DOCUMENT RESUME

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ABSTRACT

These military-developed curriculum materials consist of four volumes of individualized, self-paced text and workbooks for use by those studying to become television equipment repairmen. Covered in the individual volumes are the following topics: supervision, training, and maintenance techniques (supervision and training, safety, maintenance principles, and testing equipment); equipment maintenance (power supplies, monitoring facilities, audio systems, and color television); auxiliary equipment; and systems maintenance (troubleshooting, repair, and diagnosing system troubles). Each chapter contains objectives, coded text, exercises, and answers keyed to the text for self-evaluation. (MN)

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MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
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- Evaluating individual program needs and outcomes
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- Operating information systems and services
- Conducting leadership development and training programs

FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
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Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

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Drawer DX
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Director
1776 University Ave.
Honolulu, HI 96822
808/948-7834

TELEVISION EQUIPMENT REPAIRMAN

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Supervision, Training, and Maintenance Techniques - Student Text Page 3

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Volume 1

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Volume 2

Auxiliary Equipments - Student Text Page 313

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Volume 3

Systems Maintenance - Student Text Page 468

Systems Maintenance - Workbook Page 491

Course Description

This course is designed to upgrade the Apprentice (semi-skilled) worker to the Specialist (skilled) and/or the Technician (advanced) level. It contains basic review information as well as supervisory training. A television equipment repair person (specialist) is expected to install, maintain, repair, monitor, and analyze the performance of television systems and equipment producing radiated or cable transmitted signals. Operation and maintenance of associated test equipment is also required.

The technician level person is expected to install, troubleshoot, repair, inspect, overhaul, and modify television systems producing radiated or cable transmitted signals; maintain associated peculiar test equipment; monitor, govern, and analyze the performance of television systems; and direct performance checks and measurement of operational and spare television equipment using precision test and measuring instruments to insure continuous acceptable systems and equipment during operating periods. He/she must also coordinate activities with production agencies to insure availability of an operating system to support production requirements; and supervise television maintenance activities.

The following outlines the scope of each volume:

Volume 1A — *Supervision, Training, and Maintenance Techniques* covers not only supervision and training, but also safety, maintenance principles, oscilloscopes and test accessories, power and frequency test equipment, and electron tube and semiconductor testing.

Volume 1 — *Equipment Maintenance* discusses power supplies, sync generators, the camera chain, monitoring facilities, audio systems, and color television. The first chapter on requirements and applications was deleted because of its reference to military specific organization and forms.

Volume 2 — *Auxiliary Equipments* discusses the maintenance requirements and operation of additional equipment required to support various functions of television systems including studio lighting systems, intercom facilities, special effects, prompting facilities, audio and video recording systems as well as specialized equipment required for maintaining television equipment. A discussion of relay equipment, television VHF and UHF transmitters, receivers, antennas, and associated circuitry is presented in this volume.

Volume 3 — *Systems Maintenance* covers troubleshooting, repair, and diagnosing system troubles. The chapters on operational responsibilities and installation and modification were deleted because of references to military specific organization, procedures, and forms.

Each of the chapters has objectives, coded text, exercises, and answers keyed to the text for self-evaluation. A volume review exercise is provided, but no answers are available. This material presents basic review material as well as supervisory concerns in the television equipment repair trade for student self-study. The course would be best used in conjunction with a laboratory or on-the-job learning situation.

TELEVISION EQUIPMENT REPAIRMAN

Correspondence Course

Developed by:

United States Air Force

Development and Review Dates

Unknown

Occupational Area:

Electronics

Cost: $10.25

Print Pages: 505

Availability:
Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Suggested Background:

Basic electronics

Target Audiences:

Grades 10-adult

Organization of Materials:

Student workbooks with objectives, assignments, chapter review exercises and answers, and volume review exercises; text

Type of Instruction:

Individualized, self-paced

Type of Materials:			No. of Pages:	Average Completion Time:
Volume 1A	–	*Supervision, Training, and Maintenance Techniques*	118	Flexible
		Workbook	41	
Volume 1	–	*Equipment Maintenance*	105	Flexible
		Workbook	39	
Volume 2	–	*Auxiliary Equipment*	110	Flexible
		Workbook	41	
Volume 3	–	*Systems Maintenance*	21	Flexible
		Workbook	20	

Supplementary Materials Required:

None

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CDC 30455

TELEVISION EQUIPMENT REPAIRMAN

(AFSC 30455)

Volume 1A
Supervision, Training, and Maintenance Techniques

Extension Course Institute

Air University

DEPARTMENT OF THE AIR FORCE
UNITED STATES OF AMERICA

PREPARED BY
COMMUNICATIONS SYSTEMS DEPARTMENT
3380TH TECHNICAL SCHOOL (ATC)
KEESLER AFB, MISSISSIPPI

EXTENSION COURSE INSTITUTE, GUNTER AIR FORCE BASE, ALABAMA

THIS PUBLICATION HAS BEEN REVIEWED AND APPROVED BY COMPETENT PERSONNEL OF THE PREPARING COMMAND IN ACCORDANCE WITH CURRENT DIRECTIVES ON DOCTRINE, POLICY, ESSENTIALITY, PROPRIETY, AND QUALITY.

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Preface

IN THIS COURSE we discuss and analyze principles and maintenance of the instrument landing system (ILS), terminal very-high-frequency omnirange (TVOR), and tactical air navigation system (TACAN)—the aids to navigation classed as flight facilities equipment. The purpose of this and succeeding volumes is to assist you through self-study in obtaining knowledge necessary to perform maintenance tasks assigned to you. Emphasis is placed on principles of flight facilities equipment rather than particular models of equipment. Occassionally, specific equipment is discussed because we consider it to be representative of the type, or because it includes features also found in other equipment. An understanding of these principles is essential to all phases of NAVAIDS maintenance.

This volume deals with supervision, training, maintenance techniques, safety, and test equipment. Chapter 1 covers the supervision expected of a trained NAVAIDS repairman and your responsibilities toward the Air Force continuous training program. The second chapter is on safety, with emphasis on safe maintenance practices and emergency action. References to this subject will reccur throughout this course.

Succeeding chapters describe maintenance principles, both preventive and corrective, and include management, technical orders, test equipment, and specific procedures for printed circuits. The information in these chapters should enable you to employ test equipment confidently, choose substitutes when necessary, and evaluate measurements correctly.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to Tech Tng Cen (TTOC), Keesler AFB, MS 39534.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development, Study Reference Guides, Chapter Review Exercises, Volume Review Exercis, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If he can't answer your questions, send them to ECI, Gunter AFB, Alabama 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is rated at 36 hours (12 points).

Material in this volume is technically accurate, adequate, and current as of January 1972.

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Supervision and Training

THE QUALITY of communications-electronic's systems depends on all maintenance personnel performing their assigned tasks at the right time, in the right place, with proper equipment, and in a professional manner. To accomplish this, we must employ the basic element of all organizations—supervision. What is a supervisor? How do we become supervisors? Why are some supervisors more successful than others? These questions are simple to answer if we *memorize* short statements, but statements do not make a successful supervisor.

2. You are probably asking yourself, "Why do I have to worry about supervision?" This may be true today, but as you gain experience and knowledge, you may be placed in a position requiring managerial knowledge, such as a shift supervisor or trainer. To be a successful supervisor in this C-E career field, you must:

- Use proper management techniques.
- Train others.
- Understand maintenance management practices.
- Maintain the equipment assigned to your shop in peak operating condition by using proper maintenance techniques and applicable technical publications.

3. In this chapter we will examine only the first two items listed above. As we discuss these items individually in this and succeeding chapters, keep in mind that, in actual practice, you may be involved with some or all of these items simultaneously.

1. Supervision

1-1. The odds are highly in favor of your being a supervisor sometime during your first hitch. The Air Force works on the principle that each member of an organization must be able to lead as well as to follow.

1-2. Just what is a supervisor? A supervisor is a person who directs the efforts of one or more people in getting a job done. He is a leader and a manager as well. Not only does he lay out the details of a job, assign and advise workers, but in many cases he has to assemble equipment and materials. Further, he must rate his workers and account for their time and the materials they use. The quality of his supervision is measured by the degree of success he achieves. There are four areas we would like to explore briefly on this subject—responsibilities, employee relations, production, and performance reports.

1-3. **Responsibilities.** Responsibility is directly proportional to the importance of the assigned position. The desire to assume responsibility does not qualify a man for a supervisory job; he must be able to accept the responsibility without reservation.

1-4. As a supervisor, your responsibilities will never cease. You will have a responsibility to your mission, to higher headquarters, to your unit and other units, and to personnel under your supervision. Often, it will seem that your responsibilities conflict with each other. Under these conditions you must choose one course of action and proceed. You should have the authority to assume your responsibilities, and you must always remember never to assign responsibilities without also delegating sufficient authority to assure that the course you have chosen can be followed.

1-5. You must have the courage to "stick your neck out" when the occasion arises, to act contrary to all advice when your judgment demands it, and to be willing to take full blame when things go wrong. As a supervisor, regardless of how you personally may feel, you must be decisive and act promptly.

1-6. *Responsibility to the mission.* Responsibility to the mission is your primary objective. Your responsibilities to your unit and your personnel are secondary. There will be times when you will have to disregard the needs and feelings of your subordinates in order to accomplish the mission. At such times, the esteem your men hold for you will suffer unless they have been thoroughly indoctrinated with responsibilities to the mission. You should impress this fact upon them through talks, discussions, training, and personal example. In spite of such orientations, not all of your personnel will support you in this. There are always some who place personal desires before duty; however, they will eventually fall in line and follow the majority.

1-7. *Responsibility to your superiors.* This is another objective you must realize. When you fail to support your superiors, you jeopardize your own efforts. When you criticize your supervisors and their methods, you, in turn, invite criticism by your subordinates. They are simply following your example. To avoid this, carry out the directives of your superiors as if they were your own. Should you disagree with the directives, take up your disagreement with your superior and not with your subordinates. If the directive still stands after you have presented your disagreement, carry it out to the best of your ability without excuse, alibi, or any attempt to pass the buck.

1-8. At times you may be directed to do something contrary to directives from higher headquarters. When this happens, do not hesitate to bring it to the attention of your superior. If you are still directed to carry out his original instructions, do so without reluctance. In such a situation your superior assumes full responsibility for his action. You must realize that he is nearer to the top and knows more than you do about the overall mission. Responsibility to the mission is your prime interest, regardless of how unpleasant the order may seem.

1-9. *Responsibility to yourself.* Although you know that your commander and your workers have their own opinions of your ability; you must constantly analyze yourself. The following checklist can serve you as a guide.

a. Understand my organization.
  (1) Know the functions of my unit and how they contribute to the total mission.
  (2) Show each worker how his job fits into the overall picture.
  (3) Determine lines of authority and responsibility.
  (4) Determine number and type of workers required in my unit.
  (5) Make logical duty assignments based on clear lines of responsibility and authority.

b. Get the work out.
  (1) Give directions that are simple, understandable, and specific.
  (2) Review work for progress in meeting schedules.
  (3) Coordinate the work of my unit and take action as necessary.
  (4) See that my workers do what is rightfully expected of them.
  (5) Emphasize the control of cost.
  (6) Minimize overtime in my unit.
  (7) Resolve my production problems immediately.

c. Plan and schedule work.
  (1) Know the work capability of my unit.
  (2) Know the workload of my unit.
  (3) Plan priorities of work and schedule accordingly.
  (4) Plan for best use of manpower, space, and equipment.
  (5) Establish realistic goals for the group.
  (6) Have my group participate in setting its own goals.
  (7) Plan to meet deadlines and emergencies.
  (8) Plan and schedule overtime when necessary.

d. Improve work methods.
  (1) Analyze operations of my unit as a whole.
  (2) Evaluate present methods of performing jobs.
  (3) Develop and apply improved methods.
  (4) Encourage and assist workers in submitting their ideas.

e. Determine performance requirements.
  (1) Determine what is expected of each worker.
  (2) Discuss tentative requirements with each worker concerned.
  (3) Make final determination of requirements based on needs of management, supervisory experience, and workers' suggestions.
  (4) Evaluate objectively each worker's performance based on requirements.

f. Develop workers.
  (1) Select right person for the job.
  (2) Help worker make adjustments on new job.
  (3) Determine training needs of workers and provide training.
  (4) Measure results of training in terms of production cost and improved skills, attitudes, and other factors.
  (5) Let workers know how they are doing.
  (6) Discuss career opportunities with workers.
  (7) Develop an understudy.

g. Maintain a cooperative workforce.
  (1) See that workers are rewarded for jobs well done.
  (2) Commend entire group on performance when deserved.
  (3) Transfer and reassign workers for the best use of their abilities.
  (4) Earn worker's confidence and loyalty.
  (5) Encourage workers to discuss their problems with me.
  (6) Adjust differences fairly and objectively.
  (7) Keep workers informed.

  (8) Develop and maintain effective discipline within the work group.
  (9) Initiate corrective and punitive actions as needed.
  (10) Insure safety and welfare of workers.

h. Improve myself.
  (1) Recognize my "shortcomings."
  (2) Improve my technical knowledge and skills.
  (3) Improve my ability to get along with people.
  (4) Develop a cooperative relationship with my workers, my superiors, and other personnel.
  (5) Develop a good attitude toward my job and the base.

1-10. **Employee Relations.** Much has been written in psychology books about how you can get along better with other people. Considerable emphasis has been placed in base-level management training programs on the why and how of working with people in a team spirit to reach a common goal.

1-11. *Factors in good relations.* In place of a long discussion here on the factors concerning employee relations, we will list the normal foundations necessary for good employee relations and then present an outline of an effective procedure for handling human problems. The following items will aid you with many employee relation problems. They are not all-inclusive, but are enough to give you a start in the right direction. As you observe supervisors at work and gain experience, you can add to the list.

a. Let each worker know how he is getting along.
  (1) Figure out what you expect of him.
  (2) Point out ways he can improve his work.
  (3) Praise in public, criticize in private.

b. Give him credit where credit is due.
  (1) Look for extra or "beyond the call of duty" type of performance.
  (2) Tell him while its "hot."

c. Tell people in advance about changes that will affect them.
  (1) Tell them why, if you know.
  (2) Sell them on the idea of accepting the change.

d. Make the best use of each person's ability.
  (1) Look for that extra ability that may not be in use.
  (2) Never stand in a man's way.

1-12. *Handling problems.* You may have trouble at times handling problems. You may be confronted with difficult situations which appear to have no solution. There are, fortunately, tried and true procedures which you can use to help solve these problems. A procedure you can apply in a difficult situation is as follows:

a. Get the facts.
  (1) Review the record.
  (2) Find out what rules and regulations apply.
  (3) Talk with the individual concerned.
  (4) Get opinions and feelings.
  (5) Be sure you have the complete story.

b. Weigh and decide.
  (1) Fit all the facts together.
  (2) Consider their bearing on each other.
  (3) Decide what possible courses of action are available.
  (4) Check practices and policies of your organization at your level.
  (5) Consider the solutions and their effects on the individual or group, and on work.
  (6) Don't jump to conclusions.

c. Take action.
  (1) Will you handle this yourself?
  (2) Will you require help?
  (3) Should you refer this problem to your supervisor?
  (4) Make your decision and time your actions to fit your decision.
  (5) Don't pass the buck.

d. Check results.
  (1) How soon will you follow up?
  (2) How often will you need to check?
  (3) Observe changes in output, relationships, and attitudes.
  (4) Has your action increased or decreased the work output of the individual or group?

1-13. **Production.** Whether your unit is on a large base or at a remote site and whether your unit is responsible for organizational-, field-, or depot-level maintenance, the end results are what count. There are four natural divisions falling under production: (1) assignment of work, (2) review of work quality, (3) production controls, and (4) performance standards. First, let's look at assignment of work.

1-14. *Assignment of work.* Giving orders or making job assignments is an important and difficult part of a trainer's duties. Individuals receiving instructions are all different in their personality makeup. Some people just naturally resent being "told" what to do. Still others may not resent orders but, because of their own lack of initiative, tend to blame their supervisor for their own mistakes because of his inability to properly assign work. On the other hand, there are people who seem to have a "knack" for receiving instructions and carrying them out successfully.

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1-15. Regardless of the kinds of people in your work group, you should remember that the manner in which work is assigned may be the key to the successful completion of any job. The following 10 rules are good ones to follow when making assignments

(1) Be well informed about the work you assign.
(2) Give each man a job you know he can do.
(3) Give clear, brief instructions—speak clearly.
(4) Do not take head-nodding as understanding. Invite questions from the trainees.
(5) Repeat your instructions if they are not understood. This may save much time and unnecessary work in the long run.
(6) Give orders through proper channels.
(7) Demonstrate steps or job tasks wherever necessary.
(8) Put complex instructions in writing, choosing each word with care.
(9) Do not give too many orders at one time.
(10) Know your men—their abilities, qualifications, and limitations.

1-16. In connection with item (10), you must learn what each man can do best. Perhaps one is especially good at inspection. Another may have the knack of untying knotty maintenance problems. It's only good common sense to place a man where he can do his best work. But, remember this, just because a man does one job exceptionally well, it is not always advisable to keep him in that job indefinitely. He should be well rounded in his training, and be able to perform all of the required duties of his job description, his AFSC, and the Specialty Training Standard. Your job is easier when every man can perform well on all the duties in his specialty.

1-17. *Review of work quality.* When you inspect a completed task, give it a thorough examination—not just a quick once-over. There are at least two good reasons for a thorough check.

1-18. First, the equipment that has been worked on must operate properly for the success of the mission, and it must be in safe operating condition. Second, inspection of completed work may be turned into an excellent learning device for the man in training. Your method or technique of reviewing completed work determines the inspection's usefulness as a teaching device. Where is a better place for the trainee to learn than on the equipment?

1-19. Properly reviewing job assignments requires a considerable amount of skill and tact, as well as a thorough understanding of the mechanics of the job. As you talk to the worker, stress both the strong and weak points of his work. Praise work that has been performed skillfully but do not tolerate sloppy work. Avoid criticism, sarcasm, or personal references since these comments may cut deeper than you realize and leave the worker with a strong feeling of dislike for you. In brief, don't just use words. Demonstrate correct procedures and give the man the opportunity to correct his faults.

1-20. There is one other thing you should do. Don't check completed work only, but also check job progression. In short, don't wait until the job is finished, because a job sometimes has to be redone if an error enters the picture before the job is completed. Failure to check job progression may cause loss of time and work output and, in the end, may lead to harsh feelings and loss of ambition on the part of the man who finds his efforts wasted because he was forced to do the same job over.

1-21. *Production controls.* Production controls include mechanical and graphical standards, time budgeting, and work scheduling. Mechanical standards are largely determined by your Specialty Training Standard and the type of test equipment and tools required on the job. Graphical standards can be accomplished at the shop or higher level with specially designed forms and graphs. A chart can show you at a glance what man is working on what job, how the job is progressing, what aircraft and system is involved, and so on.

1-22. *Performance standards.* One of the biggest problems you face is the determination of performance standards. In some cases, these standards are prepared and handed to you from higher authority. In other cases, you are faced with devising standards of your own which will fit the job to be done.

1-23. You are usually faced with measuring performance from two standpoints—the individual worker and groups of workers. Usually, the task is eased somewhat by the fact that the worker in the group is doing the same type of work as his fellow workers. However, evaluation of performance must be accomplished, and it must be valid from the level of the worker as well as the supervisor.

1-24. Performance standards are day-by-day qualities which you, as a supervisor, should observe. You should make mental notes, or perhaps even written ones which may be referred to in the future. Be mentally alert and keenly observant of the jobs performed by those you supervise.

1-25. **Noncommissioned Officer and Airman Performance Reports.** Another area that you will find of major importance, as a supervisor, is the NCO and airman performance report. The preparation of this report requires many of the qualities outlined in the preceding paragraphs. The performance report requires careful attention as it is the primary tool in making nominations for training, special assignments, and other special actions. In addition, this document is an important part of the Air Force promotion system.

1-26. The importance of proper evaluation of all personnel cannot be overemphasized. As a supervisor, you have the continuing responsibility for the preparation of accurate, honest, and objective performance reports. When it becomes necessary for you to submit a report, it is imperative that you be thoroughly familiar with the instructions in AFM 39–62, *Noncommissioned Officer and Airman Performance Reports.* This manual will give you the correct form number and complete and up-to-date instructions on the preparation and submission of the performance report.

2. Training

2-1. Because of constant changes in communications and electronics equipment in the Air Force, training is a continuous requirement. When you enter the Air Force, you are trained on equipment that is currently being used. Later, as newer models are developed, you require additional training to qualify you to maintain them efficiently.

2-2. Besides the equipment, there are many other facets of your job you must learn to advance in your career field. How fast you advance depends largely upon how hard you work and how well you take advantage of the many opportunities for training to improve yourself technically, culturally, and militarily.

2-3. **General Plan for Air Force Training.** Since training is always an important part of your Air Force career, you should know the training systems and methods employed. In some instances, you are required to advise and train other airmen to acquire the knowledges and skills you already possess. But before you start training others, let us look at the systems through which you may be trained.

2-4. Although there are definite training programs preparing airmen for the many jobs in the C-E career field, each person, to a considerable extent, must look after his own interests. You already know that skill levels and promotions are related; so how do you move from the 3 skill level to the 9 skill level? For a start, look at figure 1.

2-5. This figure shows the route that your are following in your Air Force career. You attended a technical training course to reach your present 3-level AFSC. You are now entering on-the-job training (OJT) to qualify you for the 5-level AFSC. This will be followed by another period of OJT to qualify you for the 7-level AFSC. You become qualified for the 9-level AFSC by experience in the unit to which you are assigned. There is formal school training that you may take to help qualify you for the 9 level. The only mandatory prerequisite for the 9 level is a passing grade on the USAF Supervisory Test.

2-6. Another possibility is to qualify for one specialty at the 5 level, and then qualify in yet another specialty at the 5 level before advancing to the 7 level in either one of the two specialties. Such qualifications are through formal school and on-the-job training; this is known as lateral training. This means training from one ladder to another in the 30 Career Field in those AFSCs designated by Air Force Headquarters.

2-7. At various times in your career, you may be enrolled in a formal school course. You will find that these courses are identified by a combination of letters and numbers. The principal identification is the AFSC number. In addition to this, courses usually have a number plus a three-letter prefix and a title.

2-8. For example, take Course 3ABR30430, Radio Relay Equipment Repairman. The 3 tells you that it is an ATC resident technical training type course. The A tells you that it is an airman course (officer courses begin with the letter O); the B tells you that it is a basic technical course; and the R tells you that it is a resident (formal school) course conducted by the Air Training Command. The title is shown by the words "Radio Relay Equipment Repairman."

2-9. You will find a large number of courses described in Air Force Manual 50–5, *Formal Schools Catalog.* Each has a title and alphabetical-numerical identification similar to the one just described.

2-10. **The Dual-Channel Concept of On-the-Job Training.** Note by referring again to figure 1 that there are three general ways of increasing your usefulness to the Air Force and advancing your career at the same time—training in a formal technical school, on-the-job training, or a combination of these two. OJT is divided into two elements—career development and job proficiency development.

2-11. *Career development.* Career development is the acquiring of general background knowledge required for understanding military and career area functions. In this element you study the general Air Force subjects, principles of your equipment, and the specific information

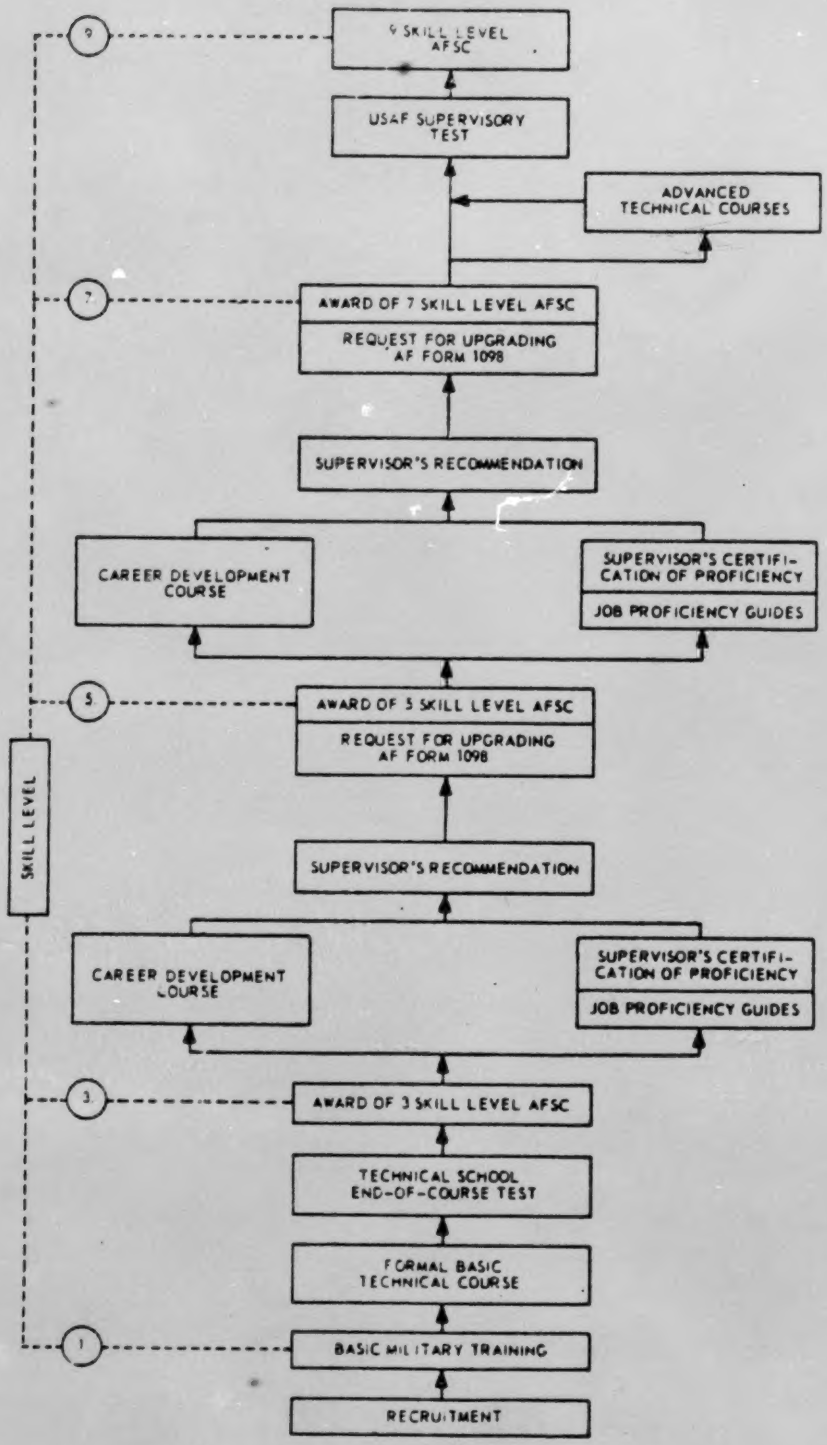
9
9 SKILL LEVEL AFSC
USAF SUPERVISORY TEST
ADVANCED TECHNICAL COURSES
7
AWARD OF 7 SKILL LEVEL AFSC
REQUEST FOR UPGRADING AF FORM 1098
SUPERVISOR'S RECOMMENDATION
CAREER DEVELOPMENT COURSE
SUPERVISOR'S CERTIFICATION OF PROFICIENCY
JOB PROFICIENCY GUIDES
5
AWARD OF 5 SKILL LEVEL AFSC
REQUEST FOR UPGRADING AF FORM 1098
SKILL LEVEL
SUPERVISOR'S RECOMMENDATION
CAREER DEVELOPMENT COURSE
SUPERVISOR'S CERTIFICATION OF PROFICIENCY
JOB PROFICIENCY GUIDES
3
AWARD OF 3 SKILL LEVEL AFSC
TECHNICAL SCHOOL END-OF-COURSE TEST
FORMAL BASIC TECHNICAL COURSE
1
BASIC MILITARY TRAINING
RECRUITMENT

Figure 1 Normal skill progression, dual-channel concept.

necessary to perform the duties of your AFS. In brief, the first step you take to qualify for a higher skill level and higher rank in the Air Force is to study the applicable Career Development Course (CDC), of which this is the first volume. This volume contains the general knowledge you need to pursue your career in whatever job you may be assigned in the 304 career field.

2-12. *Job proficiency development.* Job proficiency development is primarily the acquisition of skill by actually performing the duties and tasks of an AFSC; secondarily, it is the application of the knowledge you learned from studying the CDC. Your supervisor during your on-the-job training uses as his guide the applicable Job Proficiency Guide (JPG).

2-13. OJT involves practical application. You are placed in an operational situation requiring you to perform certain specific tasks. As you acquire skill in the simpler tasks of your specialty, you are given other tasks which are more and more difficult. Thus, you constantly broaden your knowledge and skill until you master all the elements of your job. In the meantime, the Air Force benefits from your productiveness while you are learning.

2-14. Learning in an OJT situation is the result of the close association of the trainee and the skilled technician who serves as the trainer. Note, however, that this coach-pupil method does not preclude short periods of group instruction. Group instruction is sometimes the most practical way for elaborating on matters presented in the CDC—further explanations of such things as essential theory, background material, safety precautions, and so on—that all trainees must know.

2-15. Look again at figure 1, and note that the path you have followed to qualify for the 3-level AFSC is the completion of a formal basic technical course. You proceed to the 5 level by on-the-job training. This entails satisfactory completion of the applicable CDC and receiving the supervisor's certification of proficiency based upon the standards in the JPG. You must also serve a minimum of 6 months in OJT status.

2-16. There are many supplemental special courses that offer formal school instruction in specialized areas, such as a particular model or type of radio equipment. Since these courses do not award the 5-level AFSC, you still must study the CDC, serve the minimum of 6 months in your duty assignment at the 5 level, and be recommended by your supervisor for award of the 5-level AFSC. Some of the special and supplemental courses are "shredouts" and are identified by a suffix.

2-17. As already noted, to advance still further in your career, you take a more advanced CDC, plus a minimum of 12 months in OJT, to qualify you for the 7 level.

2-18. There is one other special requirement for advancing to the 7 level. All trainees must take either ECI Course 6, *Management for Air Force Supervisors*, or a comparable on-base course usually called *Management-1 (MGT-1)*. Either management course provides you with the vital knowledge managing men and materials so that your unit can make its maximum contribution to the mission of the base. Usually, most airmen training for the 7 level take the MGT-1 course on the base. If not practicable, in isolated outposts or wherever the MGT-1 course is not given, then ECI Course 6 is acceptable.

2-19. After completing a minimum of 1 year's experience in the 7-level AFSC, completing the corresponding CDC, and being recommended by your supervisor, you will be awarded the 7 level (subject to the approval of the Consolidated Base Personnel Office, CBPO). Qualification to the 9 level is based on experience and supervisory ratings. Although there are a few 9-level formal courses, they do not qualify you for the 9-level AFSC; final award depends on recommendation of the supervisor and approval of the commander.

2-20. **OJT Record Documents.** You have been in the Air Force long enough to know that there are many records on file which concern you. This recordkeeping was started by your recruiter and continues throughout your training and total service. Although you don't establish records nor post them, you do have the responsibility of checking them for accuracy at least once a year. So far as training records go, the most important to you is AF Form 623, Consolidated Training Record, as it is your only complete record of your training.

2-21. *AF Form 623, Consolidated Training Record.* Much of the success or failure of an OJT program is determined by how well the individual training records are maintained. Completeness, currency, and accuracy of entries on the Consolidated Training Record are often determining factors in deciding award or withdrawal of AFSCs, entry into or withdrawal from OJT status, assignment or withdrawal of proficiency pay status, or selectivity for preferred assignments. The

Consolidated Training Record is an official Air Force document and requires as much consideration and care in its maintenance as any other official record. The knowledge, attention, and skill applied to the proper maintenance of training records are as important as the actual training conducted

2-22. AF Form 623 has four pages which are subdivided into 11 parts on which to record the airman's progress and proficiency in OJT. Each section is individually identified according to its designated purpose. This permits the recording of all upgrade, lateral, and retraining conducted on the job, in career development, and in formal courses. The form may also be used to record training which occurs after upgrading has taken place. A copy of the documents supporting entries to AF Form 623 may be filed with the form.

2-23. The AF Form 623 is not complete until the Air Force specialty training standard and/or the job proficiency guide for the appropriate Air Force specialty are made a part of the training records.

2-24. Since the AF Form 623 must be available immediately to the supervisor, it is ordinarily maintained in your immediate working area; however, it may be maintained in the squadron. When you are transferred, the AF Form 623 must accompany your field personnel records to the new organization. It is normally expected that training will be continued unless you are specifically withdrawn from training by the gaining organization. If the gaining organization discontinues the training, then the authority for discontinuance (appropriate personnel action or orders) must be recorded on the AF Form 623.

2-25. *Specialty Training Standard (STS).* The Specialty Training Standard for each AFSC is developed from AFM 39–1. An Air Force specialty description states the tasks which airmen must be able to perform and the knowledge they must have. By the use of the self-contained code key, the standard indicates:

a. The extent to which personnel should be trained on each knowledge and task in order to qualify for upgrading to a specified skill level.

b. The extent to which airman courses provide training on each of the listed tasks and knowledges.

2-26. Your acquaintance with this document is necessary since your initials as well as your trainer's are required to indicate that various phases of your training are completed.

2-27. In addition, it might be of interest to you to know that the Specialty Training Standard is the source of authority establishing the content of the technical training courses, one of which some of you may have completed at Keesler AFB, MS.

2-28. *Unit Document Listing (UDL).* Bare mention of this document is all that is necessary at present. The UDL gives a picture of how many airmen, by AFSC, grade, and specific job title, are available and how many jobs there are. For the AFSs which are short of personnel, additional men are trained; for those overmanned, none can be trained.

2-29. **Other Types of Airman Technical Training.** In addition to the two main types of training—OJT and resident schools—there are several other kinds. These are briefly discussed below.

2-30. *The field training program.* This training is conducted by Air Training Command field and mobile training detachments and traveling teams from ATC technical training centers. These units operate at the bases where there is a training need and they conduct formal classroom instruction for airmen. The scope of this program is worldwide.

2-31. A field training detachment is a detachment or school, controlled by Air Training Command, permanently assigned to an Air Force base or other activity. The mobile training detachment, also controlled by ATC, travels to various bases as needed. It is supported by a mobile training unit which carries along with it the necessary training aids and equipment. A traveling team consists of one or more qualified instructors sent to support a one-time training requirement at the site of the requesting activity.

2-32. The field training program encompasses a large variety of training activity. Generally, it offers the technical instruction necessary to qualify personnel in the knowledges, skills, and techniques required to successfully operate, maintain, and control assigned C-E equipment, aerospace and missile systems, and their associated direct support equipment.

2-33. Although training programs have numerous and various names, don't let that make you forget that *all* training programs have one major purpose—to qualify the right man for the right job and to assure the highest level of proficiency in operational and maintenance personnel. So, in order to qualify personnel with these capabilities, the Air Force must use as many types of training programs as practicable.

2-34. *Airman on-the-job retraining.* As provided by AFM 39–4, retraining is designed to qualify an airman in an Air Force

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specialty not in the progression ladder of a currently awarded AFSC. The principal objectives of on-the-job retraining are:

a. To reduce the number of surplus airmen in grade and skill by retraining them into required grades and skills.

b. To prevent indiscriminate retraining of airmen from required grades and skills.

2-35. In other words, the Air Force endeavors to maintain a supply of airmen in the grades and skills that are needed by initial training or by retraining them from grades and skills that become surplus.

2-36. If you should be retrained, you would move from the career field in which you presently hold an AFSC into another career field, or you might train to qualify for a different suffix to your AFSC.

2-37. *Special training.* Special training is formal training that qualifies you in maintaining new or special equipment. Normally, all special training courses are short and are designed to meet emergency requirements. No AFSC is awarded upon completion of a special training course unless specifically approved by Headquarters USAF.

2-38. For futher information concerning the administration of on-the-job retraining and on-the-job training under the dual-channel concept, you can refer to the Air Force manuals which prescribe the administration of these programs. These manuals are AFM 50–23, *On-the-Job Training* and AFM 39–4, *Airman Retraining/Lateral Training Programs.*

2-39. At this time, work the chapter review exercise for Chapter 1 in your workbook.

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CHAPTER 2

Safety

TWO PRINCIPAL factors to consider when you learn how to maintain any piece of Air Force equipment are: how to maintain the equipment properly, and how to maintain it safely.

2. Though you may think of these two factors as being one in the same, there is a difference for the purpose of our discussion in this chapter. Of course, if you don't maintain equipment properly, you may, at the same time, be maintaining it unsafely, for improper maintenance is often the cause of accidents. Furthermore, you may maintain a power saw properly and, at the same time, get careless and find your hand or fingers in the path of the whirling blade. So, let us think of maintaining equipment in the two ways stated—properly (getting the job done quickly and accurately) and safely (preventing any injury to yourself or others).

3. In this chapter you will learn about good housekeeping, accident causes, fire prevention, first aid, radioactivity, off-duty safety, and accident reporting.

4. You might ask yourself, "Why is safety so important?" Offhand, you might say, "Because is saves lives, prevents injuries, and protects property." Well, that's true enough, but there are some other important reasons. You want to earn promotions and progress in your career, don't you? Of course. You'll find that your supervisors will note not only how efficient you are on the job but also how safely you work. They aren't interested in productivity at the cost of preventable accidents. If you're a safe worker as well as an efficient one, you will stand a better chance of earning that promotion and also win the approval of your fellow airmen. If you know the principles and practices of safe operation of shop equipment, you'll be able to give a timely warning to a fellow airman—a warning that might even save his life!

3. On-Duty Safety

3-1. The safety-conscious airman knows that accidents are preventable and that good housekeeping and good fire prevention practice will eliminate most of them. The safe and successful completion of a job demands neatness and cleanliness in the work area.

3-2. **Good Housekeeping.** The first rule of good housekeeping is personal cleanliness. If you are an orderly person and present a good appearance, it will probably be reflected in your work. A person who keeps himself clean has developed a habit which is carried over into all his actions. You have made a great stride in the right direction if you have learned to keep yourself and your clothing neat and clean.

3-3. Next, there is your work area. Many accidents can be prevented, and much loss of time and pain may be avoided if you keep your work area clean and orderly. For example, oil spilled on the floor can cause you or another to slip and be injured seriously. If oil or fuel is spilled, cover it with an approved compound; or better still, clean it up immediately. Keep the floor or ramp free of obstructions. You can trip over an extension cord or a dropped tool and injure yourself.

3-4. Some units that you will disassemble have small parts which can be easily lost, broken, or mixed with other parts. To avoid the loss of time while you hunt or acquire another part, keep your bench top in a neat and orderly condition. A cluttered bench makes effective work almost impossible and is the starting place for an accident. Worn out or reparable parts should be disposed of promptly in the correct places—not on the floor.

3-5. Other items that always find their way into your work area are soft drink bottles. They should be kept in the break area and in the proper container. A broken bottle is a very dangerous object. Candy and gum wrappers belong around candy and gum—or in a waste basket. Never drop gum on the floor. It soils the floor when you step into it, and can cause a fall.

3-6. Every shop has a designated place for toolboxes when they are not in use. Keep them in place and keep the lids closed. It does not require much time or effort to open the box

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when you need a tool, and you may prevent someone from cutting or bruising his shin. Most shops have a tool board to keep special tools available to all who may need them. Keep unused tools in their proper place.

3-7. If your shop maintains a stockroom, keep cases and other goods stacked neatly in the prescribed location and to the designated height. This prevents damage to the stored items and also makes them easily available when they are needed.

3-8. Good ventilation is conductive to good work. Ventilation is actually necessary for the good health and safety of personnel. Your work output drops off considerably if you are uncomfortably hot or cold, or if there is a lack of fresh air. If the air is dusty in your shop, or if fumes are present, consult your supervisor or trainer so that he can be made aware of the conditions under which you are working and can take the necessary corrective action.

3-9. Proper lighting is another requisite for doing good work. Definite standards have been set up by the Air Force to provide the correct illumination for all installations. These should be followed, since good lighting works hand in hand with good housekeeping to eliminate many accident hazards.

3-10. **Accident Causes, Effects, and Controls.** It is true—accidents are preventable. The law of cause and effect is the basic ingredient in all accidents. Accidents do not happen without a reason, and the identification, isolation, and control of causes are the basic procedures of all accident prevention techniques. Even natural elements can be controlled to some extent, and it is only in the realm of such phenomena as lightning, storms, or floods that accidents are extremely difficult to prevent. However, even the effects of these can be minimized, as in the case of securing aircraft when strong winds are expected.

3-11. *Indirect causes.* Theoretically, preventable accidents may be traced to causes originating in the heredity and environment of individuals. These beginnings may further manifest themselves in unsafe personal characteristics which allow an individual to perform an unsafe act or overlook or tolerate an unsafe condition which may result in an accident. The injuries, property damage, and loss of combat capability which follow complete the costly sequence. The detection and elimination of unsafe personal characteristics, such as inattentiveness, excitability, impatience, and stubborness, are normally extremely difficult. On the other hand, the elimination of unsafe acts and conditions is a relatively simple and effective means of accident prevention.

3-12. *Direct causes.* As the last and most obvious element of the cause sequence preceding an accident, unsafe acts and conditions may be considered the immediate or direct cause of any accident. When this direct cause is removed, the sequence is interrupted and the accident cannot happen. Usually, unsafe acts and conditions can be anticipated, readily identified, and eliminated almost immediately upon discovery. Because of this, practical accident prevention measures are designed to prevent or eliminate direct causes, and suitable controls have been developed for this purpose.

3-13. Approximately one-fifth of all USAF ground accidents result from Government motor vehicle operations. However, less than 5 percent of all injuries to military and civilian personnel are attributed to this source, since not all motor vehicle accidents result in personal injury. Of the total number of these accidents, some three-quarters are caused by unobserved backing, excessive speeds for road conditions, exceeding speed limits, following too closely, and failure to yield right of way. All of these unsafe acts can be eliminated.

3-14. Approximately two-thirds of the total Air Force accident experience remaining is sustained in activities such as aircraft and motor vehicle maintenance, sports and recreation, and domestic activities.

3-15. *Direct costs.* Each year accidents cause hundreds of deaths and thousands of injuries to Air Force personnel. These fatalities and injuries, most of which could have been prevented, impose a tremendous direct cost on the Government for medical care, insurance payments, claims, compensation for civilian employees, and related services. Accident costs, carefully computed over a representative period of time, permit accurate estimates of the average direct cost of each fatality, injury, and first aid case. When these costs are added together, the total is staggering, and should emphasize to everyone the necessity for preventing accidents. Equally as important as money costs is the toll in human suffering—something that cannot be evaluated in dollars and cents.

3-16. An additional drain on Government funds happens when equipment, property, and supplies are destroyed or damaged by preventable accidents. Not only is the cost of repair or replacement significant, but operations may also be seriously handicapped if parts or replacements are not immediately available. When aircraft or motor vehicles are out of operation for any length of time, assigned missions may be delayed, and in a tactical situation the results could be critical.

3-17. *Indirect costs*. In addition to direct costs, every accident involves indirect costs estimated to be several times those that can be readily counted. Indirect costs include the loss of time and production of the injured and those who aid them, time lost by curious or sympathetic people at the scene of the accident, time lost in investigation, cost of training replacements, interference with operations, and damaged equipment. Though less tangible than direct costs, indirect losses can be computed and totaled in the overall cost of any accident. Any installation can establish a valid indirect cost ratio by calculating these losses over a representative period of time and comparing the total with equivalent direct costs. Studies indicate that the ratio of indirect to direct costs is at least 4 to 1. For every one dollar of direct accident costs, there are at least four dollars of indirect costs. Again, these losses can be prevented!

3-18. *Accident control*. Usually accidents can be prevented through adequate safety engineering and education. But there are some people who are a hazard to themselves and others because they fail to comply with accepted safety standards. It is these persons for whom the strict enforcement of safety practices is necessary, backed by prompt corrective action. No organized accident prevention effort can be successful without effective enforcement, because accidents are frequently the direct result of the violation of safety principles. This is particularly true of vehicle accidents, many of which are caused by unsafe acts constituting traffic law violations.

3-19. To be completely effective, accident prevention controls cannot be applied "hit or miss." All engineering, education, training, supervision, and enforcement measures must be based on factual evidence and directed toward the solution of specific problems. Only in this way can controls be adequately applied.

3-20. **Fire Prevention.** Closely allied with good housekeeping and absolutely necessary for any organization is a smooth working fire prevention system, since the best cure for any fire is to prevent its occurrence. To do this requires that you carry out all safety precautions with regard to the prevention of fires. It also means that you must know what to do and how to do it when a fire does occur.

3-21. *Precautions*. Many fires are caused by carelessness and poor housekeeping. Oily rags thrown in a corner are excellent material for a healthy fire. Poor storage practice, especially of inflammable materials, has caused many avoidable fires. Overloaded electrical outlets coupled with defective circuit breakers may also cause a fire. No smoking signs were made to be observed; lighted cigarettes and matches thrown in wastepaper baskets full of paper are not usually put out by the fall. Here are a few precautions that you should observe with regard to fire prevention; you can probably add to the list from your own experiences and warnings that you have read or heard.

a. Do not allow oily rags to accumulate.

b. Observe the signs in the NO SMOKING areas.

c. Never allow your clothing to become saturated with fuel or oil. If it should become that way accidentally, change your clothing as soon as it is possible.

d. Do not permit gasoline, kerosene, jet fuel, or any other inflammable fuels to be stored in open containers.

e. Always make sure that the static lines are in place and that the aircraft is grounded properly before you work on it.

f. Never deposit cigarettes or matches in a wastebasket even if they appear to be out.

g. Do not open any oxygen valve near a flame or a lighted cigarette.

3-22. When fires do occur, you must be ready to fight them quickly and effectively. This means that you should know the telephone number of the base fire department, the location of the fire extinguisher, and which type of extinguisher to use for the type of fire you are fighting.

3-23. The telephone number for the base fire department is usually posted in large letters. These posters are spaced at intervals in the shop, in the barracks, and on the flight line. As a rule, the base telephone directory has this number printed in large letters on the cover page or on one of the first pages of the book. If alarm boxes are installed on your base, learn where they are and how to use them.

3-24. *Fire extinguishers*. Fire extinguishers for the most part look alike, but a fire can increase if you use the wrong type of extinguisher on it. Figure 2 shows you what types of fires each extinguisher can be used on and its effective range. Above all, find the location of the fire extinguisher in your work area, determine what type it is, and plan how you are going to use it if the occasion should present itself.

3-25. **Radiation Prevention.** You may, in the future, be required to work around radioactive material or materials that have been contaminated by radiation. You must be aware of the safety precautions to observe and, above all, you must instantly recognize the radiation

Type of Extinguisher	Pump-Tank	Soda Acid	Foam Types	Carbon Dioxide	Chloro-bromomethane
Use on:	Type A Fires: Wood, trash, paper, waste.	Type A Fires: Wood, trash, paper, waste.	Type B Fires: Gasoline, oil and oil base material, varnishes, etc.	Type C Fires: Electrical fires, confined fires on oil, ordinary combustibles.	Type Fires: Electrical fires.
May also be used on:	--------	--------	Wood, trash, paper, waste.	Type A and B fires.	Small fires.
Method of using.	Direct stream at base of flames.	Work close for penetration. Direct stream at base of flames.	Apply complete blanket of foam over surface. Avoid a direct stream on oil surfaces.	Apply so that gas floods material in a wave-working with draft. Extinguisher lasts only a few seconds.	Direct stream on base of fire or hot surface.
Effective range	--------	30 to 40 feet	30 to 40 feet	3 to 6 feet	15 to 30 feet
Principle of extinguishment	--------	Cools burning surfaces below ignition point. Any stream generated tends to smother flames. Practically no gas leaves nozzle.	Blankets burning material with froth or foam, which excludes oxygen. Cools and insulates surface from heat. Blanket prevents flashbacks.	Flame is smothered by heavy blanket of nonflammable gas.	Upon contact with flame or hot surface, the liquid converts into a heavy smothering vapor.
Warning	Never use on charged electrical equipment, varnish, oils or other fuels. Protect from freezing.	Never use on charged electrical equipment, varnish, oils or other fuels. Protect from freezing.	Never use on charged electrical equipment. Protect from freezing.	CO_2 will not support life. Avoid extended exposure in area where it has been used, especially in pits.	Do not use in closed areas. If liquid comes into contact with skin or eyes, wash immediately with water followed by medical treatment.

Figure 2. The use of common fire extinguishers.

warnings. We have prepared a general list of precautions that must be observed. Remember, you cannot see radioactivity and it may be several hours before you feel the effects of radiation.

3-26. *Precautions.* Observe the following rules when you work around radioactive material:

a. You must have a physical examination if you are exposed to radiation. If you are working around radiation, you will be scheduled for an examination periodically.

b. Be sure that the base monitor briefs you on the measures and hazards involved.

c. You must wear protective clothing while working around radioactive materials.

d. Always wear a film badge and or a pocket dosimeter when you are around radioactivity.

e. Practice good hygiene. Wash your hands and face thoroughly before eating or smoking.

f. Do not eat, drink, smoke, or chew gum in the area.

g. Report any scratch or cut made by a radioactive object. Such scratches may cause severe sores and be very slow in healing.

h. Do not wear personally owned items such as watches and rings. They may become contaminated.

i. Do not handle telephones, reports, or other similar objects while you wear protective gloves. Your gloves may contaminate them.

j. Do not breathe dust or metallic particles which come from radioactive materials.

3-27. *AFTO 9 series.* The AFTO 9 series forms help you identify radioactive material. These forms are yellow with a red symbol. The 00-110A series technical orders contain a complete description of the forms and instructions for handling contaminated items. Figure 3 shows a radiation warning placard, AFTO Form 9C. Be alert for radiation warning placards, tags, or tables; any time you see one, take the necessary precautions.

3-28. The AFTO 9 series forms and their sizes are listed as follows:

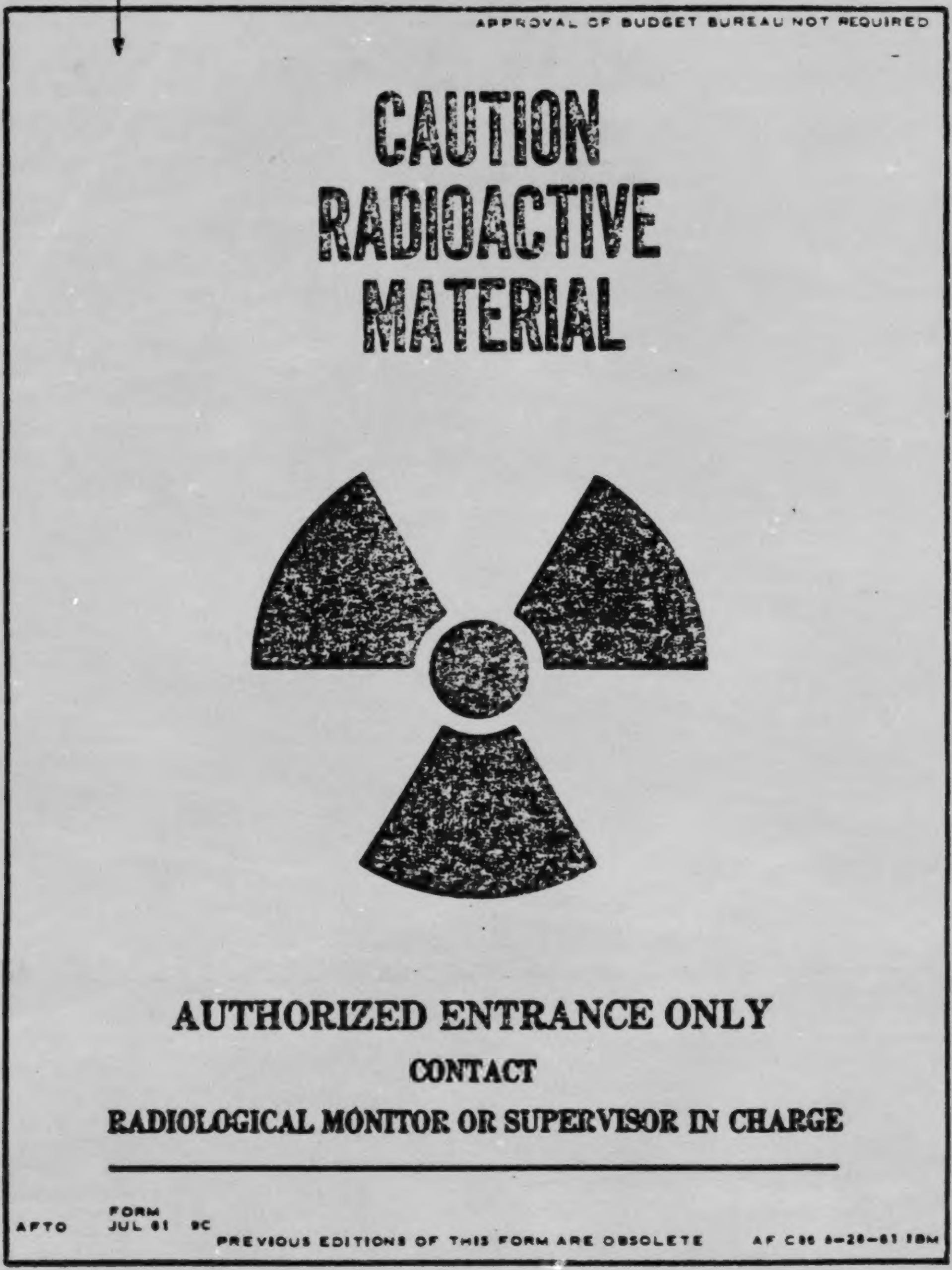
a. AFTO Form 9, Radiation Warning Placard, is 18 × 24 inches.

b. AFTO Form 9A, Radiation Warning Tag, is 3 1/2 × 6 1/4 inches.

YELLOW BACKGROUND

MAGENTA INSIGNIA

BLACK TYPE



APPROVAL OF BUDGET BUREAU NOT REQUIRED

CAUTION
RADIOACTIVE
MATERIAL

AUTHORIZED ENTRANCE ONLY

CONTACT

RADIOLOGICAL MONITOR OR SUPERVISOR IN CHARGE

AFTO FORM JUL 61 9C

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE

AF C86 6-28-61 IBM

Figure 3 Radiation warning placard.

c. AFTO Form 9B, Radiation Warning Table, is 6 1/2 × 6 inches.

d. AFTO Form 9C, Radiation Area Restriction Placard, is 18 × 6 inches.

e. AFTO Form 9D, Radiation Ingestion Hazard Placard, is 8 1/2 × 11 inches.

f. AFTO Form 9E, Area Restriction, No Radiation Material Placard, is 14 × 5 inches. This placard warns personnel about taking radioactive material into the posted area.

3-29. **Accident Reporting.** If you are involved in an accident, your supervisor and the ground safety office will be required to fill out forms reporting the circumstances and the extent of damage and injuries sustained. Although there are several forms, the USAF Form 711 and 711a, Ground Accident/Incident Report, is the one that will concern you most. Your supervisor will complete this form from your information. Your cooperation will be necessary. Accidents are reported on forms prescribed by AFR 127—4 and involve:

- Injuries to Air Force military and civilian personnel or those stationed, assigned, or employed at Air Force installations.
- Injuries to non-Air Force personnel resulting from Air Force ground operations.
- Accidents and incidents resulting in disabling injuries and/or property damage of $25 or more. Such accidents are referred to as "reportable ground accidents." When an accident is reported for any of the foregoing reasons, all injuries without regard to their extent or amount will be included.

4. First Aid

4-1. Air Force Pamphlet 50—55, *GMT First Aid*, is an excellent publication for studying first aid. But first aid is so important to you, to your friends, and even to total strangers that the fundamentals should be repeated in this publication.

4-2. There are two types of emergencies that few people escape meeting some time in their lives. These emergencies require first aid or lives can be lost. They are: (1) emergency treatment of wounds or serious cuts and (2) artificial respiration for victims of electrical shock or drowning.

4-3. You don't have to be a doctor or medical technician to help an injured person. For that matter, accidents seem to happen more often than not beyond the convenience of professional help. The life of an injured person, therefore, often is held in the hands of many people. Let's be sure we are ready.

4-4. **Emergency Treatment.** To treat a wounded person, you should be able to carry out the three life-saver steps which follow:

- STOP the bleeding.
- PREVENT or TREAT shock.
- PROTECT the wound.

Memorize these three steps and learn the simple methods of carrying them out.

4-5. *Control of bleeding.* Uncontrolled bleeding may cause or increase shock and result in death. Stop any severe bleeding immediately. To stop bleeding, first apply pressure to the wound with a dressing or, if necessary, some substitute material such as a clean shirt, handerchief, etc. Be sure to use clean materials. Place the dressing or cloth against the wound and apply firm pressure. See figure 4. Continue the pressure as long as needed. Use an additional dressing to cover the wound if necessary. Wrap the tails of the dressing around the wounded part and tie the ends to hold the dressing firmly against the wound.

4-6. If the wound is on an arm or leg and if the bleeding continues, place the patient on his back with the wounded arm or leg raised. The bleeding is only slowed, not stopped, by raising the arm or leg, so you still have to use the dressing and pressure. DO NOT raise the limb if you think the bone is broken. Moving a broken arm or leg is dangerous, since it may result in further injury to the victim and may increase shock.

4-7. Often you can reduce or stop bleeding by applying hand or finger pressure at various points on a patient's body. The locations of these points are shown in figure 5. The pressure

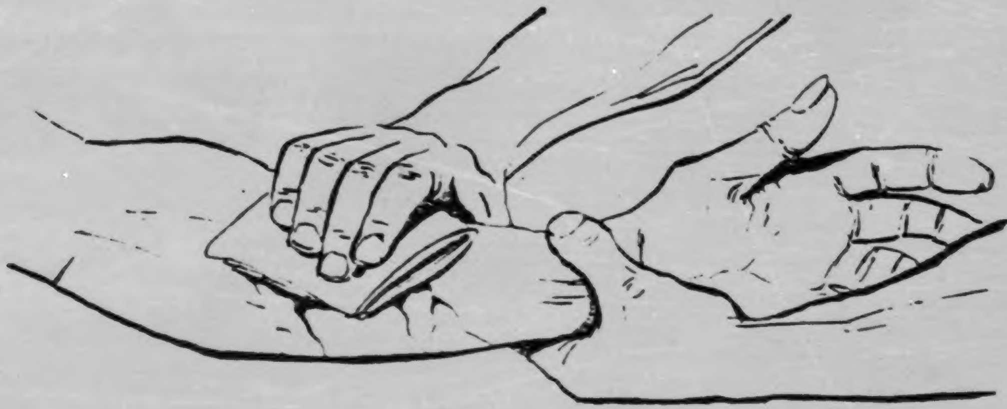


Figure 4. Stop the bleeding—pad or dressing.

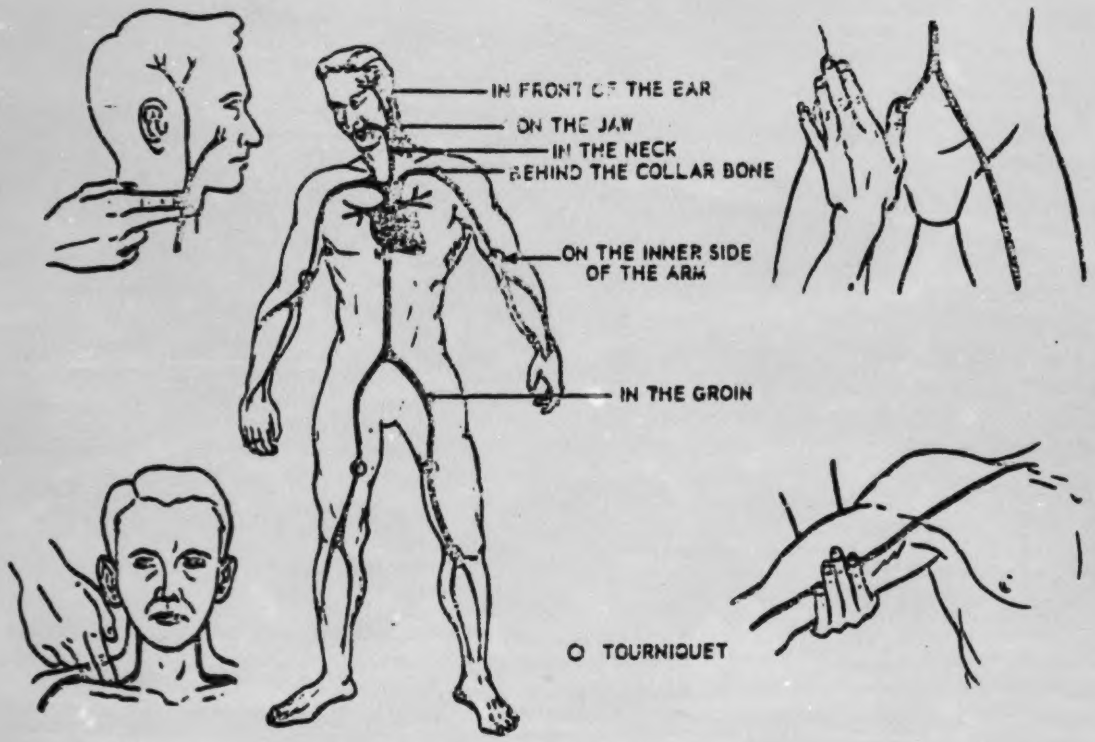


Figure 5. Stop the bleeding—pressure points.

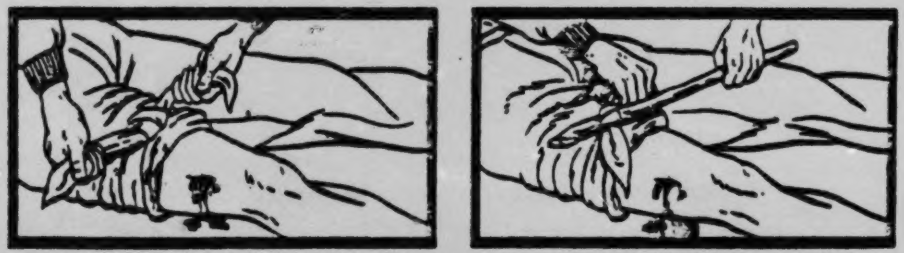
points in the groin and neck are particularly important. If the wound is too high on the leg for a tourniquet to be applied, the pressure points in the groin can be used. A neck pressure point should be used when the casualty has a profusely bleeding scalp wound. Use the neck pressure point only as a last resort when other methods of stopping bleeding have failed. Figure 4 shows a means of applying pressure with the hand. This method may also be used on the head and neck pressure points, using the index and middle fingers. The heel of the hand is used to apply pressure to the groin. CAUTION: Do not apply pressure to both neck points at the same time. You would cut off the blood supply to the brain, which would cause unconsciousness and death.

4-8. A tourniquet should be used only for severe, life-threatening hemorrhaging that cannot be controlled by other means. It should be used only when severe bleeding involves an extremity in which the large arteries are severed, or in case of partial or complete severance of a body part. These are the only instances where the application of a tourniquet is justified. If necessary to use a tourniquet, follow the procedure illustrated in figure 6.

4-9.. A tourniquet should be tightened only enough to stop arterial bleeding (gushing of blood from the wound). The veins will continue to bleed slightly until the limb is drained of all blood; thus, bleeding will not be reduced by further tightening of the tourniquet.

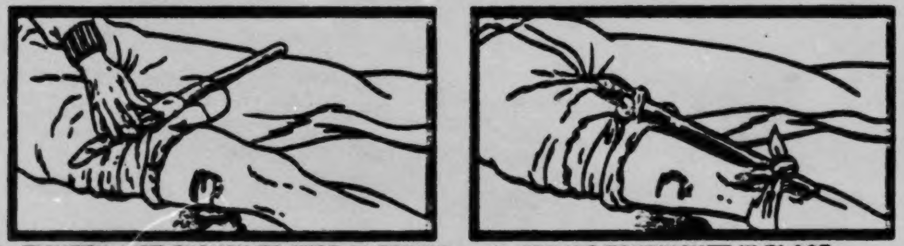
4-10. Always place the tourniquet between the wound and the heart, and, in most cases, as low as possible above the wound. However, in the case of bleeding below the knee or elbow, a tourniquet should be placed just above the respective joints. When possible, protect the skin by putting a tourniquet over the smooth sleeve or trouser leg. CAUTION: The victim should be seen by a medical officer as soon as possible once the tourniquet is applied. The tourniquet should not be loosened by anyone except a medical officer prepared to stop the bleeding by other means and to restore the blood volume by transfusion. Repeated loosening of the tourniquet by inexperienced personnel is extremely dangerous, because the life of the individual is endangered by further loss of blood.

4-11. *Prevention and treatment of shock.* Shock is a condition of great weakness of the body. It can, and often does, result in death



1. MAKE A LOOP AROUND THE LIMB.

2. PASS A STICK UNDER THE LOOP.



3. TIGHTEN JUST ENOUGH TO STOP BLEEDING.

4. SECURE TOURNIQUET IN PLACE

Figure 6. Stop the bleeding—tourniquet.

Shock may be caused by any kind of injury; and the more severe the injury, the more likely the occurrence of shock. Shock may not appear for some time after injury. Always treat an accident victim for shock whether or not he has symptoms of shock.

4-12. Symptoms of shock are not difficult to recognize. A person in shock may show one or more of the following conditions:

a. He may tremble and appear nervous.

b. His pulse becomes rapid and weak.

c. He may be excessively thirsty.

d. He may become quite pale and wet with sweat.

e. He may gasp for air and may even faint.

f. He may vomit or complain of nausea.

Again, remember to treat for shock. Don't wait for one of the above symptoms to appear.

4-13. The same procedures are used to prevent and to treat shock. The first step is to make the victim comfortable. He should be kept lying down in order for greater amount of blood to flow to the head and chest where it is needed most. Loosen his belt and any other tight-fitting clothing. Make sure there are no broken bones before you move him. Cover him to keep him warm and prevent chilling. If he is unconscious, place him face down with his head turned to one side to prevent choking should he vomit. If he is conscious, give him some liquid (nonalcoholic) to drink to replace body fluid.

4-14. *Protect the wound.* The third and final step is to protect the wound from infection and further injury. Tear or cut the clothing around the wound and be careful not to touch it with your hand. Cover the wound with a sterile dressing and bandage if available. Do not touch the side of the dressing that goes next to the wound. Tie something around the body or limb to hold the dressing securely in place. Once the dressing is applied, do not remove it.

4-15. **Artificial Respiration.** Artificial respiration is a means of causing air to flow into and out of the lungs of an individual when his normal breathing system ceases to function.

4-16. *Uses.* Artificial respiration is not restricted to the treatment of victims of electrical shock. Even though we are primarily concerned with electrical shock in this discussion, we should also mention a few additional uses for artificial respiration. It may also be used to stimulate breathing in individuals whose breathing has stopped as a result of drowning, carbon monoxide or other gas poisoning, smoke, overexposure to heat, or suffocation. When breathing is inadequate, the victim is always pale or blue in color. In carbon monoxide poisoning, the symptoms may be giddiness, weakness, headache, vomiting—then unconsciousness.

4-17. *Obstructions to breathing.* An important consideration in any method of artificial respiration is that the air passageway be open. If there is an obstruction, air cannot enter the lungs regardless of the method used. There are three main causes for obstruction. The first is liquid, false teeth, or other foreign matter in the mouth or throat. The second is

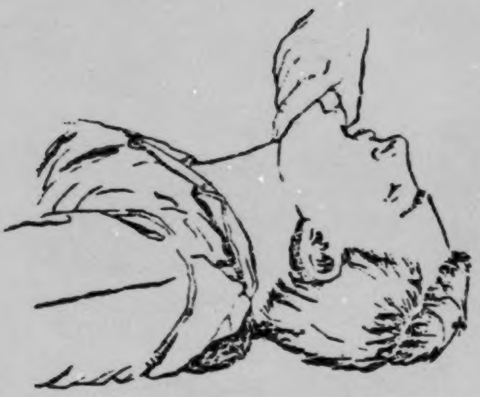


Figure 7. Pulling the lower jaw outward.

relaxation of the jaw. The tongue, attached to the relaxed jaw, falls backward and blocks the throat (called "swallowing the tongue"). The third is the position of the neck. When the neck is bent forward so that the chin is down close to the chest, there is a tendency for the throat to become "kinked" and block the passage of air. The air passageway can be kept open by placing the head in a position with the chin jutting outward.

4-18. *Methods.* There are four basic methods of artificial respiration recognized by the Air Force. They are as follows:

- Mouth-to-mouth (exhaled-air).
- Back-pressure-arm-lift (B-P-A-L).
- Back-pressure-hip-lift (B-P-H-L).
- Chest-pressure-arm-lift (C-P-A-L).

Of the four methods, the mouth-to-mouth method has proven to be the most effective because it can be used even though the victim has suffered severe burns or injuries. It is the surest method for getting oxygen into the lungs and should always be used when conditions permit.

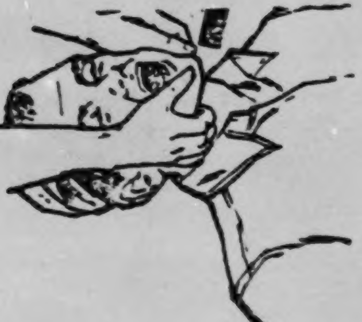


Figure 8. Pulling the lower jaw outward on children.

4-19. Using the mouth-to-mouth (exhaled-air) method you force air into the victim's lungs with your own mouth. Since you retain only a portion of the oxygen from the air which you inhale, the air you breathe into the victim's lungs contains a sufficient amount of oxygen to revive him.

4-20. The step-by-step procedure for administering mouth-to-mouth artificial respiration is as follows:

Step 1. Turn the victim on his back.

Step 2. Clean the mouth, nose, and throat. If foreign matter such as vomit or mucus is visible in the mouth, nose, and throat, wipe it away quickly with a cloth or by passing the index and middle fingers through the throat in a sweeping motion. When these areas appear to be clear, proceed as quickly as possible.

Step 3. Place the victim's head in the "sword-swallowing" position. The head must be placed as far back as possible so that the front of the neck is stretched.

Step 4. Hold the lower jaw up. Approach the victim's head, preferably from his left side. Insert the thumb of your left hand between the victim's teeth at the midline as shown in figure 7. Pull the lower jaw forcefully outward so that the lower teeth are further forward than the upper teeth. Hold the jaw in this position as long as the victim is unconscious. A piece of cloth may be wrapped around the thumb to prevent injury by the victim's teeth. In the case of young children (under age 3), where your thumb would obstruct too much of the mouth, or in a victim whose mouth cannot be opened, proceed as follows. Grasp the angles of the lower jaw just below the ear lobes with both of your hands, one on each side of the victim's head as shown in figure 8. Lift the lower jaw forcefully outward so that the lower teeth are further forward than the upper teeth. At the same time, pull the lower lip down with the thumbs to open the mouth. Hold the jaw in this position as long as the victim is unconscious.

Step 5. Close the victim's nose by compressing it between the thumb and forefinger of the right hand as shown in figure 9. In the case of young children or in a victim who has tight jaws, block the victim's nose to prevent air leakage by pressing your right cheek against the nasal opening as shown in figure 10. (The hands will be occupied elsewhere.)

Step 6. Blow air into the victim's lungs. Take a deep breath, and cover the victim's open mouth with your open mouth making an airtight contact. In the case of a baby, the rescuer's mouth can cover both the mouth and nose with an airtight contact. Blow rapidly until the chest rises. If the chest does not rise when you blow in, improve the position of the

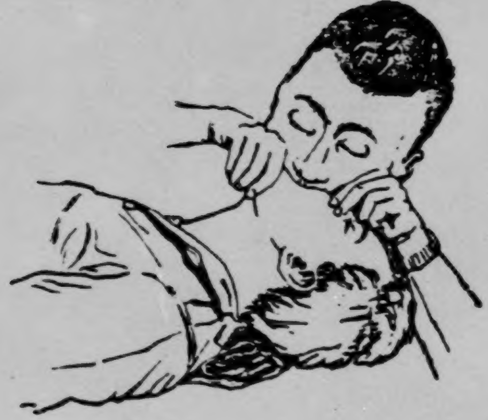


Figure 9. Closing the victim's nose.

victim's air passageway, and blow more forcefully. Always blow forcefully into adults and gently into children.

Step 7. Let air out of the victim's lungs. After the chest rises, quickly break lip contact with the victim, and allow the victim to exhale by himself. Repeat steps 6 and 7 vigorously at an approximate rate of 12 times per minute for an adult. Use shallow puffs of air at the rate of 20 times per minute for a child. A smooth rhythm is desirable, but split-second timing is not essential. Continue rhythmically without interruption until the victim starts breathing or is pronounced dead.

4-21. An alternate method of the exhaled-air method can be accomplished with the use of a plastic device called an airway, which is shown in figure 11. This device tends to increase efficiency because it prevents the tongue from falling back into the throat. It also is more sanitary. But never refrain from administering the oral mouth-to-mouth method because this device is not available. CAUTION: DO NOT use this plastic device on children under 3 years of age.

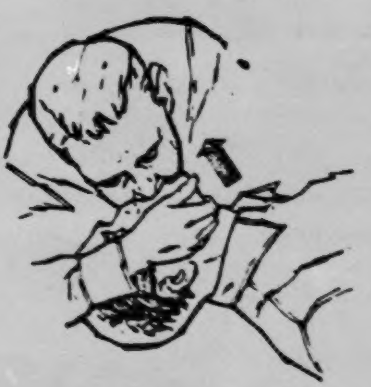


Figure 10. Closing the victim's nose in the case of small children.

4-22. The procedures are the same as for the oral method with the exception of your position and placing the airway in the victim's mouth. Extreme caution should be exercised when inserting the airway so as not to damage the throat.

4-23. Assume a position at the top of the victim's head. Insert the long end (short end for children 3 years of age and over) into the throat while holding the head back as shown in figure 12. If necessary, hold the tongue down to prevent it from getting in the way while inserting the airway. Insert the airway until the flange rests lightly against the lips. Once the tube is inserted, retain the same position and place the hands as shown in figure 13. Pinch the nose with your thumbs and press the flange with your index fingers to prevent any air leakage. Be sure to hold the chin upward and toward yourself at all times.

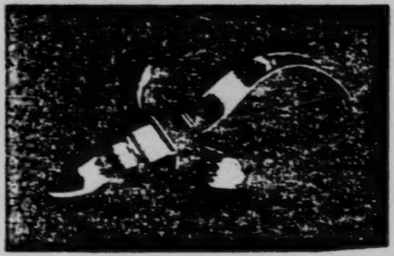


Figure 11. Plastic device.

4-24. Blow into the tube, watching for the chest to rise, as indicated by figure 14. When the chest moves, remove your mouth and allow the victim to exhale. Repeat this process in the same manner as in steps 6 and 7 of the oral method. The first obvious indications that the victim is responding to your efforts will be a gurgling or gasping for air sound and possible coughing and gagging.

4-25. If the victim appears to be breathing to some degree, keep his air passageway open until he awakens by maintaining the support of his lower jaw. If his tongue or fingernails are blue rather than pink, he is not breathing adequately and still requires assistance. You should breathe air into the victim's lungs each time the victim himself breathes in. Synchronize your timing to assist him.

4-26. After either method of exhaled-air artificial respiration has been performed for a period of time, the victim's abdomen may bulge from the air blown in the victim's stomach. Air inflation of the stomach is not dangerous;

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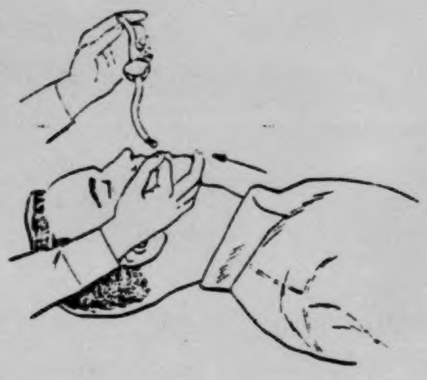

Figure 12. With device—first step.

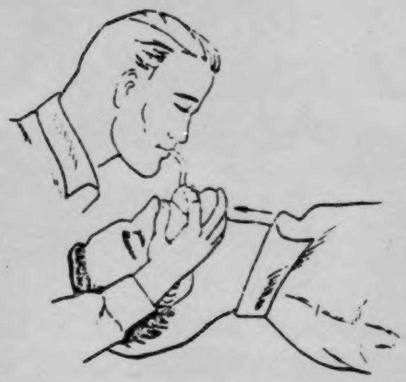

Figure 14. With device—third step.

however, inflation of the lungs is much easier when the stomach is empty. If the rescuer sees the abdomen bulging, he should interrupt blowing for a few seconds and press with his hand on the upper abdomen between naval and breastbone, causing the air to be "burped." Since this maneuver may cause the victim to vomit, the rescuer must be ready to roll the victim's head to the side and clean the throat at once.

4-27. The drowning victim usually swallows large amounts of water. When the rescuer performs the first few breaths of exhaled-air artificial respiration, the water may be forced from the stomach into the victim's throat because of pressure transmitted through the diaphragm by the extending lungs. The rescuer must be alert to this possibility and roll the victim's head to the side immediately so that the water and other materials may drain out. Exhaled-air artificial respiration should be resumed as quickly as possible.

4-28. The drowning victim may or may not have water in the lungs. This water cannot be removed from the lungs satisfactorily by any means; however, exhaled-air artificial respiration will still be effective.

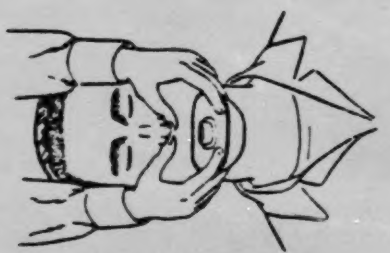

Figure 13. With device—second step

5. Off-Duty Safety

5-1. A man assigned to a hazardous operation as part of his daily duty is conscious of that danger and prepares himself accordingly. He is also under almost constant supervision during duty hours and is told what he should and should not do to remain alive and healthy. He knows that if he violates regulations and directives he will be reprimanded or disciplined for his wrong doing. Thus, he is kept in line.

5-2. Now follow this same airman after hours. He showers, relaxes, and looks around for some recreation. His carefulness usually relaxes right along with his body. Perhaps he decides to go to the hobby shop, play some sport, or go for a drive. For these activities, there is no safety officer to caution him; many times, there are no posters to warn him and no supervisor to admonish him. He is strictly on his own, and, as the facts and figures prove, often without the ability to handle the assignment. Let's take a look at some of the hazards that might confront this airman and what he should do to meet them. This section will deal with such items as safe driving during off-duty hours, safety in sports, safe conduct in the barracks, and safety in hobby shop activities.

5-3. **Safety in Driving.** As a source of off-duty pleasure, the automobile rates top billing with Air Force personnel. Unfortunately, it is also their greatest threat to life and limb. For example, in 1966 private motor vehicles driven by Air Force personnel were responsible for more than 443 deaths and 3,150 disabling injuries, and those statistics haven't improved in 1971.

5-4. About one-fifth of all Air Force ground accidents can be directly attributed to unsafe operation of private vehicles. These accidents are many times more severe than accidents in Government vehicles, with injuries reaching approximately one-third of all ground accidents. The major contributing factors to private vehicle accidents include exceeding or dropping far below speed limits, improper speeds for road conditions, fatigue and falling asleep, disregarding traffic controls, driving on the wrong side of the road, following too closely, and unsafe or improper passing. These causes account for approximately 90 percent of the unsafe acts of drivers.

5-5. What can you do to reduce the off-base, off-duty accident rate? First of all, learn the traffic laws that are in effect in your particular location. Second, observe these laws strictly. Consider several factors ragarding the exact observance of traffic laws.

- Never try to travel too far in too short a period of time. This can be assured by your adhering to the local travel policies.
- Don't continue driving when you are sleepy or overtired. Remember that when you have an accident you endanger not only yourself but the driver and passengers of other vehicles as well.
- Make sure your car is in good mechanical condition before starting on a trip. Malfunctioning brakes, lights, and windshield wipers, as well as badly worn tires, are very conducive to auto accidents.
- Keep in mind that alcohol and driving do not mix.
- Observe speed limits; highways are not intended to be race tracks.

5-6. You can undoubtedly add many more precautions to the ones listed. So, if you want to go on living with a whole and sound body and have a desire to help others do the same, drive carefully.

5-7. **Safety in Sports.** Sports should occupy a very important place in your Air Force life. Military planners are becoming more and more conscious of this fact as a means for helping people do their jobs better and develop themselves physically. Among the more common athletic activities sponsored by the Air Force, both during duty hours and off duty, are swimming, football, boxing, wrestling, basketball, baseball, track, and golf. When properly organized and supervised, these activities do much to train the airman physically and mentally. However, when engaged in improperly, they become a source of danger and often a cause of injury.

5-8. You will do well to read the *Air Force Sports Manual*, AFM 215–2. This Air Force publication, intended primarily for athletic directors, will prove itself very helpful to you in developing an attitude of sports safety.

5-9. **Safety in Barracks.** At first glance, barracks life seems to be perfectly harmless. However, by the very fact that so many different types of men are living in one building, the barracks can be a source of a great many accidents which are not always accidental.

5-10. Horseplay should never be tolerated in the barracks. During morning cleanups and G.I. parties, serious injury can be and often is caused by happy-go-lucky broom and mop wielders who exhibit their prowess as fencing experts rather than cleaners.

5-11. Smoking in bed is a practice that leads to many unpleasant results. Dispose of cigarette butts in butt cans and not in the center aisle of the bay. In case of a fire in the barracks, use the same procedure for extinguishing and reporting fires as we have already outlined.

5-12. **Safety in the Hobby Shop.** The base hobby shop, and most modern bases have one, is a good place to relax after a day's work and do something useful and practical with your spare time. Even though most hobby shops are built and equipped with a realization that the using personnel are not fully skilled in what they are doing, you must still exercise care in using the equipment provided.

5-13. Carpentry equipment is especially dangerous. Such tools as motor-driven saws, power drills, and other wood-shaping equipment should be used with caution and according to directives. Failure to do so could result in irreparable bodily injuries. Here are a few desirable items which every hobby shop user should note.

- Make sure you are well oriented on the use of equipment.
- Use safety guards at all times.
- Make sure the floor around machines is free from stumbling and tripping hazards.
- Keep the floor clear of sawdust and scraps.

5-14. Bear in mind that hobby shop SOPs were written for your protection and to insure that the equipment will fulfill its rated time of serviceability. It is to your advantage to become completely familiar with all operating procedures before you attempt to use any piece of hobby shop equipment.

5-15. At this time work the Chapter Review Exercise for Chapter 2 in your workbook.

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CHAPTER 3

Maintenance Principles

IN THE MODERN communications-electronics field, operational requirements have placed unbelievable demands on C-E systems. Now our equipment must be faster and more accurate, with performance capabilities unheard of even a decade ago. Communications-electronics systems must be capable of providing communications around the world under all environmental conditions.

2. Basically, *reliability* must be manufactured into the equipment, but another aspect—maintenance—will affect this reliability. Poor reliability results in failure, which jeopardizes the success of the mission; therefore, equipment has to be designed for ease of maintenance. But even with all the methods we now have to reduce the maintenance effort, complex electronic equipment must still be maintained by a well-trained repairman. This is you. You are a vital contributor to the reliability of the equipment. You are depended upon to report failures and to feed back data from which the causes of failures may be determined. Maintenance of the equipment is, of course, your responsibility.

3. Retaining equipment in, or restoring it to, a serviceable condition requires the application of established maintenance procedures—troubleshooting and repair. To do your work, you must thoroughly understand electronic principles and must become familiar with the operation of the equipment systems. You must know proper troubleshooting and repair principles, and how to use applicable technical publications such as technical orders, schematics, and wiring diagrams. (Note: We discuss technical orders in the last section of this chapter.) Repair principles include repair of printed circuits, replacement of transistors, and cable fabrication. Finally, you must know how to test the finished job in a minimum of time.

6. Preventive Maintenance

6-1. The best maintenance is preventive in nature, with potential failures being detected and corrected before they have a chance to develop. Preventive maintenance consists of the measures taken periodically or when needed to achieve maximum efficiency in performance, to insure continuity of service, to reduce major breakdowns, and to lengthen the useful life of the equipment or system.

6-2. This form of maintenance consists principally of inspecting, cleaning, and lubricating equipment during periodic inspections. It is aimed at discovering conditions which, if not corrected, may lead to malfunctions that will require major repair. A typical example of this type of maintenance is a requirement for the bearings of a motor to be lubricated at given intervals. If this is not done, the bearings may become dry and burn up and possibly destroy the whole motor and other associated equipment. Today some motors have sealed bearings that are permanently lubricated, but the thought behind the scheduled maintenance procedures applies to all electronic equipment.

6-3. **Inspection, Cleaning, and Lubrication.** Inspecting, cleaning, and lubricating electronic equipment is one of the most important jobs that you have as an electronic equipment repairman. Most of this work is done as you perform preventive maintenance routines. While you are performing these routines, you should be continuously alert for potential defects in the equipment, such as worn parts or overheated components. Find the cause of these defects, and correct the trouble. If you perform routines properly, you greatly lessen the possibility of future failures and malfunctions.

6-4. Technical manuals of preventive maintenance instructions outline the step-by-step procedures to follow when you inspect, clean, and lubricate equipment. The purpose of this section is to give you the general principles upon which these procedures are based.

6-5. *Inspection.* One of the most important steps in performing preventive or corrective maintenance is a complete visual inspection. Many defects in electronic equipment are found this way. You must visually inspect the equipment for discolored, burnt, or cracked resistors and capacitors, loose connections; loose mountings; faulty tubes; sluggish or dirty relays, overheated transformers and motor housings, and defective insulators. The importance of the visual inspection cannot be overemphasized. Make this inspection *very carefully.* Many simple troubles have been overlooked and their correction has become time-consuming because someone neglected to perform the visual inspection properly.

6-6. At times potential troubles can be found by *touch.* As an example, feel the coupling transformers. They should be cool even after the equipment has been operating a relatively long time. If they are hot, something is wrong. The transformers in the power supplies should be rather hot, but not hot enough to burn your hand.

6-7. During the inspection, carefully note the areas that will require special attention when you start cleaning the equipment. Most dust can be easily removed by a vacuum cleaner, but more stubborn dirt, grime, grease, and corrosion require other methods of cleaning.

6-8. *Cleaning.* The first step in cleaning electronic equipment is to remove all dust, dirt, and foreign particles with a vacuum cleaner or compressed air. When cleaning with compressed air, be careful that it does not damage fragile parts and be sure that the alignment is not disturbed by your careless handling of the air nozzle. Damage can be prevented by not using excessive air pressure and by careful handling of the air hose. A soft dust brush can be used to some advantage, provided you exercise the proper care. After the loose dirt has been removed from the equipment, use a clean lintless rag moistened with *approved* cleaning solvent to remove remaining dirt and grease spots.

6-9. Proper precautions must be observed in the storage and use of cleaning solvents. Trichloroethylene is one recommended solvent for cleaning electronic equipment. Note, however, that trichloroethylene is toxic and should be used *only* in a well-ventilated room. Where reference is made in technical publications to the use of carbon tetrachloride for cleaning purposes, trichloroethylene is to be substituted. Carbon tetrachloride is *eight times* as toxic as trichloroethylene and no more effective as a cleaner. Trichloroethylene should *not* be used for cleaning thermoplastics, "doped" coils, or natural rubber.

6-10. Remove any corrosion found during the visual inspection. Clean dirty, corroded tube pins and relay prongs with crocus cloth or fine (# 0000) sandpaper and then wipe them clean with a dry cloth. Clean fuse ends and cable connector pins in the same manner.

6-11. *Lubrication.* For lubrication instructions, use the applicable equipment technical manuals in your organization. Equipment technical manuals give you specific instructions on the type of lubricants to use, how to apply them, and the intervals at which they will be applied. The following, however, is applicable to the lubrication of any electronic equipment:

- Before lubrication, clean all the surfaces to be lubricated with a lint-free cloth dampened with a solvent.
- Do not overlubricate. Accumulation of oil or grease and dirt may cause serious damage to movable parts.
- Wipe off excess lubricant to prevent its dripping on electrical parts.

6-12. **Climatic Deterioration Prevention.** The purpose of climatic deterioration prevention is to help prevent arcing, frequency drift, short circuits, and the general deterioration caused by excessive humidity, condensation, and the resultant growth of fungus. These are constant threats to electronic equipment operation. The treatment to minimize these deteriorating forces is listed in the USAF publication, AFTO 12−1−3, *Climatic Deterioration Prevention Treatment, Electronic Test and Communications Equipment.*

6-13. You should be particularly concerned with the need for climatic deterioration prevention in hot, humid areas. Normally, you will not be required to do this type of work unless you are performing depot-level maintenance. But even if you are not allowed to perform this job in your unit, you should recognize adequate treatment and the need for additional treatment. Some adverse climatic conditions and their effects are listed in the following paragraphs.

6-14. *Relative humidity.* This is a term describing the relative amount of water vapor in the air. It is usually expressed as a percentage of the total amount of water the air can hold at a given temperature. Thus, 50 percent means the air contains one-half the total water it can hold, and 100 percent means it contains all it is capable of holding. Air can hold more water as its temperature increases. In tropical areas the relative humidity varies between 60 and 100 percent. This high humidity accounts for the condensation of moisture, or sweating, on various parts of radio and radar equipments when they undergo temperature changes. Condensed moisture on insulating materials reduces their insulating qualities and results in arc-over and shorts between terminals. The water vapor may also be absorbed by the insulation. The treatment described later slows down the absorption of moisture and keeps condensation away from the terminals. High humidity also causes corrosion of metals. Other sources of moisture include fog, salt spray, and rain, which cause similar deterioration of insulation.

6-15. *Temperature.* In general, equipment may encounter extreme temperatures, ranging from −65° F. to a maximum of 135° F., under various conditions of high humidity, fog, rain, salt spray, salt air, cold, insects, fungi, dust, etc.

6-16. Variations of temperature cause moisture to be breathed through any small cracks, pinholes, or vents in the equipment. As the temperature rises, the air inside a piece of equipment expands and is expelled, in part, through the openings and vents. When the temperature falls, the air inside the equipment contracts, and outside air is admitted through all openings and vents. The moisture which is breathed into the equipment destroys the insulating qualities of dielectrics and corrodes the metal. Keeping the filaments turned on helps keep equipment dry. This method, however, depends on local policy and conditions.

6-17. *Fungus.* This is a form of plant life that feeds on materials of vegatable and animal origin, including paper, cotton, and such things as dead insects and other fungi. It may be spread by wind, dust, dirt, and insects such as ants, flies, and mites. Growth may take place on materials other than those of organic origin if a spot of dust or other nutrient substance is present. Fungi thrive in high humidities and temperatures. Fungus growth causes decay, accelerates the deterioration of insulating materials, and short-circuits items such as relays, jacks, and keys. A fungicidal compound in the coating material used in climatic deterioration treatment retards the growth of this fungus.

6-18. Some of the effects of moisture and fungi are contained in the following list. Be familiar with the effects of moisture and fungi on materials and parts. Read and study this list carefully.

- Moisture causes swelling that may move the supports out of alignment, resulting in binding of parts.
- Moisture provides electrical leakage paths, causing flashover and crosstalk.
- Fungus growth reduces resistance between parts mounted on plastic to an extent where the item is useless.
- Rotting caused by moisture destroys tanning and protective materials.
- High temperature and moisture vapor cause rapid corrosion.
- Different metals having different potentials cause electrolysis when moisture is present.

6-19. **Climatic Deterioration Treatment.** There is a preventive treatment which, if properly applied to electronic equipment, provides a reasonable degree of protection. It guards against fungus growth, moisture, corrosion, salt spray, insects, cold, desert heat, etc. The treatment consists of using an approved lacquer or varnish coating applied with a spray gun and/or brush. A brief description of the procedure in the proper sequence is as follows:

- Make all repairs and adjustments necessary for the proper operation of the equipment.
- Disassemble the equipment and strip it as far as necessary to reach inaccessible points.
- Clean all parts thoroughly of dirt, dust, rust, and fungi. Cover parts such as air capacitors, relay contacts, and open switches with masking tape.
- Dry equipment thoroughly to dispel moisture that the circuit elements have absorbed.
- Spray all circuit elements with two or three coats of protective compound.
- Allow equipment to dry; it must not remain tacky.
- Remove masking tape and touch up with a brush all points missed by the spray.
- Reassemble the equipment.
- Retest, readjust, and realign the equipment; mark all sets with MFP (moisture fungi-proofed) to show that they have been treated.

7. Corrective Maintenance

7-1. Corrective maintenance is defined as "returning equipment to operational status or serviceability." Obviously, this return to operational status first requires locating and repairing the trouble in the equipment. Since location of troubles is commonly referred to as "troubleshooting," corrective maintenance can be more completely defined as "troubleshooting and repairing electronic equipment." Corrective maintenance

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procedures are outlined in the appropriate equipment manuals. A more detailed discussion of testing principles appears in the TO 31—1—141 series, *Basic Electronics Technology and Testing Practices.*

7-2. Because your career field includes a large number and variety of equipments, we shall not discuss how to apply corrective maintenance to specific equipment. Instead, we shall discuss generally the principles of corrective maintenance. You must know something about basic measurements, the availability of troubleshooting data, troubleshooting, repair, alignment, and performance testing.

7-3. **Basic Measurements.** In order to perform checks (performance tests) and troubleshooting, the repairman must be thoroughly familiar with the principles and use of test equipment. You must apply all the basic measurement principles required in doing corrective maintenance. You must be able to measure voltage, current, resistance, waveshapes, frequency, power, modulation, standing-wave ratio, and field intensity, and to test electron tubes. Checklists for minimum performance standards, contained in technical manuals, prescribe the required standard to be followed. These tests are an inherent part of troubleshooting and should be used whenever possible.

7-4. In corrective maintenance, you troubleshoot in order to locate the defective system, component chassis, circuit, and, finally, the defective part. After replacement or repair, you must test the unit (or the system), and apply the performance-testing criteria. Therefore, it is imperative for you, the repairman, to learn how to make all the different measurements. The order in which the basic measurements are given is not a specific order of preference. Any measurement can be a first step, depending upon your ability to azalyze the existing problems and then to correct them.

7-5. *Voltage and current measurements.* In a properly operating electronic circuit, the values of voltage and current in the circuit fall within certain specific limits. Hence, a voltage or current measurement can given us an excellent clue as to the cause of a malfunction.

7-6. Point-to-point voltage measurements, compared with available voltage charts, help us to locate troubles quickly and easily. The repairman should keep in mind that, in certain cases, a voltmeter (particularly one of low sensitivity used on a low range) may distrub some circuits to such a degree as to render them inoperative. As a rule, current measurements are not often taken in the course of testing, unless the ammeter is an integral part of the equipment under test.

7-7. *Resistance measurements.* Because resistance measurements are valuable when you are locating trouble, many maintenance manuals contain point-to-point resistance charts that are referenced to points in the equipment. Without these charts our resistance measurements in a complicated circuit are slow process. Sometimes we must unsolder one side of a particular resistor in order to prevent erroneous readings. Two precautions to be taken when an ohmmeter is used are: (1) the circuit under test must have all power removed, and (2) any meters, tubes, or tansistors that may be damaged by the ohmmeter must be removed before any measurement is undertaken.

7-8. *Waveform measurements.* Waveform measurements are very important, and are applicable to all electronic devices. It is necessary that you know the waveforms associated with a circuit. After observing these on an oscilloscope, you can determine whether the circuits are operating normally. You must remember, however, that all oscilloscopes have certain limitations. You must know these limitations before you can properly evaluate the waveshapes.

7-9. *Frequency measurements.* It is very important that receivers and transmitters be accurately set to their assigned frequencies. Setting a transmitter or receiver to a specific frequency is generally done with a frequency-measuring device. There are several types of frequency meters, some more accurate than others. Quick frequency checks are generally make with a simple resonant-circuit wavemeter. We will discuss frequency meters in more detail in Chapter 5 of this volume. Since the wavemeter is very sensitive, it is very useful in determining the fundmental frequency in a circuit having multiple harmonics.

7-10. In the UHF band, the extremely small values of capacitance and inductance required for resonance make it necessary to use either a resonant-cavity or a resonant coaxial-line type of wavemeter. Since both the resonant-cavity and the resonant coaxial-line type wavemeter absorb less energy from the circuit under test, these wavemeters are more accurate than either the reaction or theathe absorption types. If either is calibrated against a primary frequency standard, you may use it as a secondary frequency standard.

7-11. Another method of measuring ultrahigh frequencies makes use of a Lecher line. A meter indicates the peaks (or nulls) of a standing wave that appears on a folded wire or bar (Lecher line) that is resonated to that particular frequency. The distance between the peaks (or nulls) is measured, and the wavelength is calculated.

7-12. *Power measurements.* The measurement of DC power and low-frequency AC power presents little or no problem to the electronic repairman. But, as frequency increases, you need a variety of power-measuring instruments and a knowledge of their operation and application.

7-13. In the course of routine maintenance, power-level and power-output measurements in the audio-frequency range have to be made. These measurements are generally expressed in decibels (power ratios). The decibel indicates the power in a circuit with respect to zero or to a standard reference level. The power output of a transmitter is generally measured with a thermocouple ammeter in conjunction with a dummy load. Absolute power is not measured often, since routine operating indications provide enough information about transmitter performance. In the UHF portions of the spectrum, power is measured with a meter employing a temperture-sensitive element or bolometer.

7-14. *Modulation measurements.* When intelligence is superimposed on an RF carrier, a phenomenon known as modulation takes place. RF may be modulated in amplitude, frequency, or phase. Each method of modulation has certain advantages over the others. However, at this point we are concerned with measuring the degree of modulation.

7-15. The transmitter carrier is adjusted so that efficient modulation takes place. When the percent of modulation is low, the transmitter efficiency is not fully utilized; when it is high (in excess of 100 percent), serious distortion results. Precise amplitude-modulation measurements are made with an oscilloscope. They may show the actual modulation envelope or a trapezoidal pattern, depending on the method of connecting the oscilloscope to the transmitter under test.

7-16. *Standing-wave ratio measurements.* As you recall, these measurements are useful for the purpose of repair, preventive maintenance, checking, and making adjustments to transmitters. A transmission line that is not terminated in its characteristic impedance has standing waves of voltage and current along its length. These are caused by reflections occurring at the end of the line. The reflected wave varies continuously in phase in much the same way that the incident wave varies. At points a half-wavelength apart, the voltage is maximum. At points one-quarter of a wavelength from each voltage maximum, there is a voltage minimum. The ratio of the maximum to minimum voltage is known as the *voltage standing-wave ratio* (VSWR), or frequently, the standing-wave ratio (SWR). A high SWR indicates a poor impedance match which results in a loss of power in the line, and a low SWR indicates a good match with low loss in the line. An SWR of 1:1 is perfect and is seldom obtained.

7-17. *Field intensity measurements.* The magnitude of a radio wave at a given point is known as the field intensity or field strength of that wave; it is usually measured in millivolts or microvolts per meter. The field strength of a radio wave is determined by measuring the RF voltage induced into a receiving antenna.

7-18. Several types of test equipment for measuring field strength (known as ratio test sets and field strength meters) are available for each frequency range. They make it possible to measure either the relative or the absolute magnitude of field intensity produced by an excited transmitter antenna. They also enable us to determine the efficiency and the directivity characteristics of the antenna. These measurements are useful when we are (1) selecting transmitter antenna sites, (2) making surveys of field intensities, and (3) locating sources of radio-frequency interference.

7-19. The measurement of relative field strength can be made with rather simple test equipment; sometimes a grid-dip meter will suffice. Other test equipment circuits use a pickup antenna, a diode (or crystal), and a microammeter. With this type of equipment, the meter reading indicates the relative strength of the field acting on the pickup antenna; it is not directly proportional to the field intensity (because of the nonlinearity of the crystal).

7-20. **Troubleshooting Data.** When troubleshooting, you must use all available resources—such as specific data on your equipment (this data is found in TMs), measurement techniques, and personal experience of fellow workers. The technical manual for a particular unit or set contains a detailed explanation of the theory of operation of each circuit in the unit, block diagrams, practical wiring diagrams, and schematic drawings of each circuit. It shows the locations of test points and the readings (voltage and resistance) or waveshapes that should be present. The TM also contains troubleshooting analysis charts, alignment, and minimum performance checks.

7-21. *Diagrams.* The block diagrams show the mechanical and the electrical interrelationships between the stages in the systems. You must become thoroughly familiar

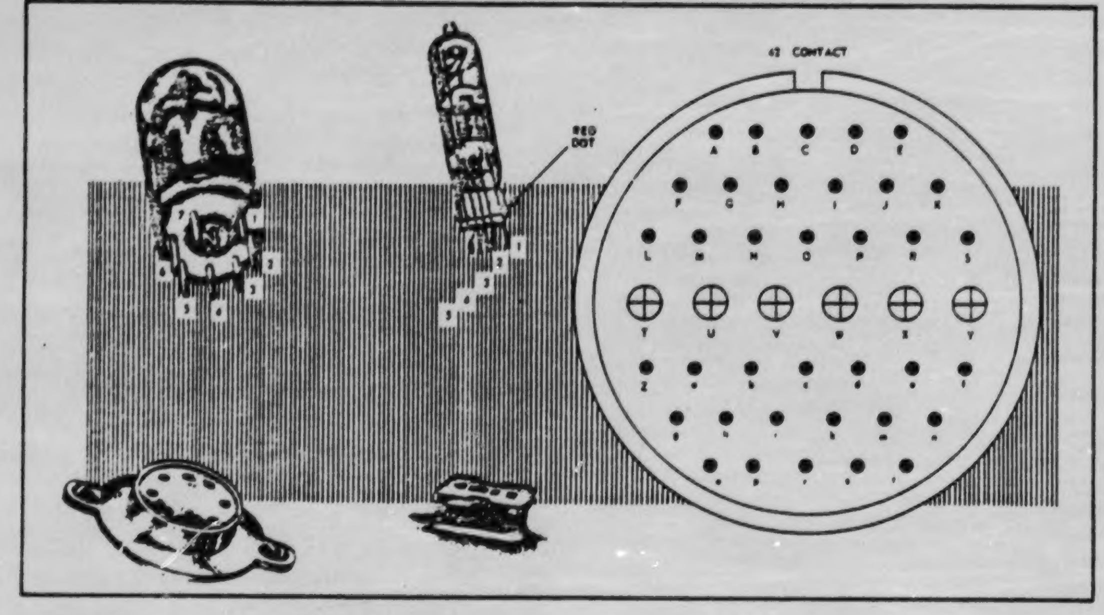


Figure 15 Vacuum tube, plug, and connector numbering system.

with block diagram analysis in order to properly apply troubleshooting principles.

7-22. Schematic diagrams include all components and show all the connections (power, input, and output) to other units. They are shown in boldface type in the list of illustrations of TMs so that they can be located rapidly. These diagrams will greatly aid you in locating faulty components.

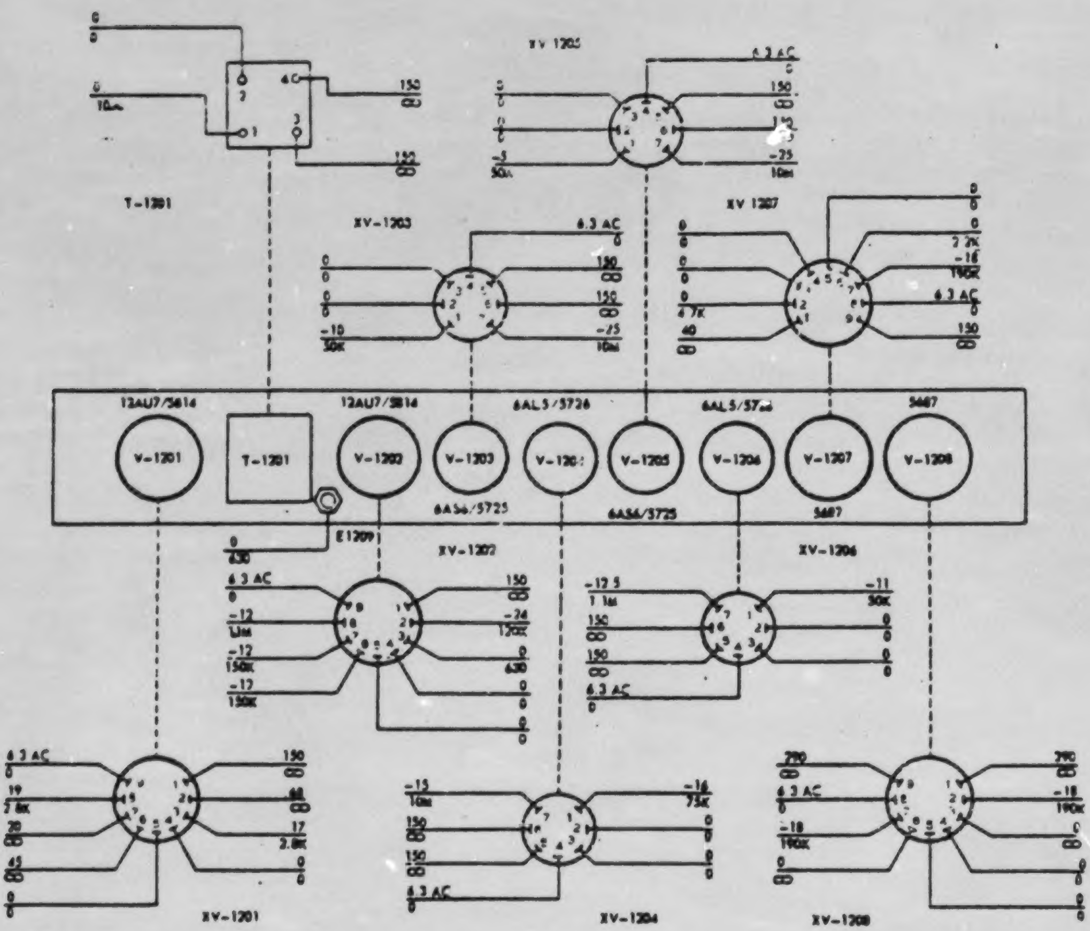
7-23. *Socket and connector data.* Viewed from the bottom, pin connections on tubes and tube sockets are numbered in a clockwise direction, as viewed in figure 15. If viewed from the top, they are numbered in the counterclockwise direction. For example, on octal sockets the first pin clockwise from the keyway is pin 1. Pin numbers appear both on the schematic and the wiring diagrams so that any tube element can be readily located. Figure 15 also shows an example of a tube and its socket, which are counted from right to left of the red dot.

7-24. Figure 15 is an example of a typical plug connector. Generally, plug connectors are numbered on the side to which the associated connector is attached. To avoid confusion, some individual pins are identified by letters which appear directly on the connector.

7-25. The voltage and resistance charts contained in the equipment technical orders show the normal voltage and resistance values at the pins of the connectors and tube sockets. Figure 16 is a typical chart showing the measurement values at each connection. When taking meter readings, you must comply with all information contained under "NOTES."

7-26. *Component illustrations.* In the process of troubleshooting, it is sometimes difficult to locate components. Front, top, and bottom views aid us in locating and identifying parts. The illustrated parts breakdown contained in technical orders presents a pictorial view of all components in the unit. An example of a pictorial illustration is shown in figure 17. The information contained therein is required when ordering parts. Pin connections at tube sockets, plugs, and receptacles are numbered or lettered on the various diagrams.

7-27. **Troubleshooting.** A communications-electronics equipment repairman is like a detective. He must find out whether or not a piece of equipment is working properly. And if not, *why* not. When you run through a performance test, you are looking for clues to tell you how the equipment is operating. If you discover that the operation of the equipment is not up to the standards, or if trouble has been reported, you must continue your detective work. Troubleshooting is a process of elimination. There are indications that give definite clues as to where the trouble may be.


T-1201
XV 1205
XV-1203
XV 1207
12AU7/5814
12AU7/5814
6AL5/5726
6AL5/5726
5687
V-1201
T-1201
V-1202
V-1203
V-1204
V-1205
V-1206
V-1207
V-1208
6AS6/5725
6AS6/5725
5687
E1209
XV-1202
XV-1206
XV-1201
XV-1204
XV-1208
6.3 AC
150
∞
-25
10M
-10
50K
2.2K
-16
190K
4.7K
630
-12.5
1.1M
-11
50K
-24
120K
-15
-16
75K
290
-18
190K

NOTES

1–ALL VOLTAGES AND RESISTANCE READINGS MEASURED TO GROUND UNLESS SPECIFIED OTHERWISE

2–SUBASSEMBLY IS REMOVED FROM MAIN CHASSIS WHEN MAKING RESISTANCE MEASUREMENT

3–RESISTANCE IS SHOWN IN OHMS UNLESS MARKED "K" FOR KILOHMS OR "M" FOR MEGOHMS.

4–ALL VOLTAGES ARE D.C. POSITIVE MEASURED WITH A SIMPSON MODEL 260 MULTIMETER UNLESS INDICATED OTHERWISE.

5–*INDICATES A VACUUM TUBE VOLTMETER USED.

6–UNLESS OTHERWISE STATED, ALL MEASUREMENTS ARE TAKEN WITH ALL CONTROLS IN MAXIMUM CLOCKWISE POSITION

7–"C" – TUBE CONDUCTING
"NC" – TUBE NOT CONDUCTING.

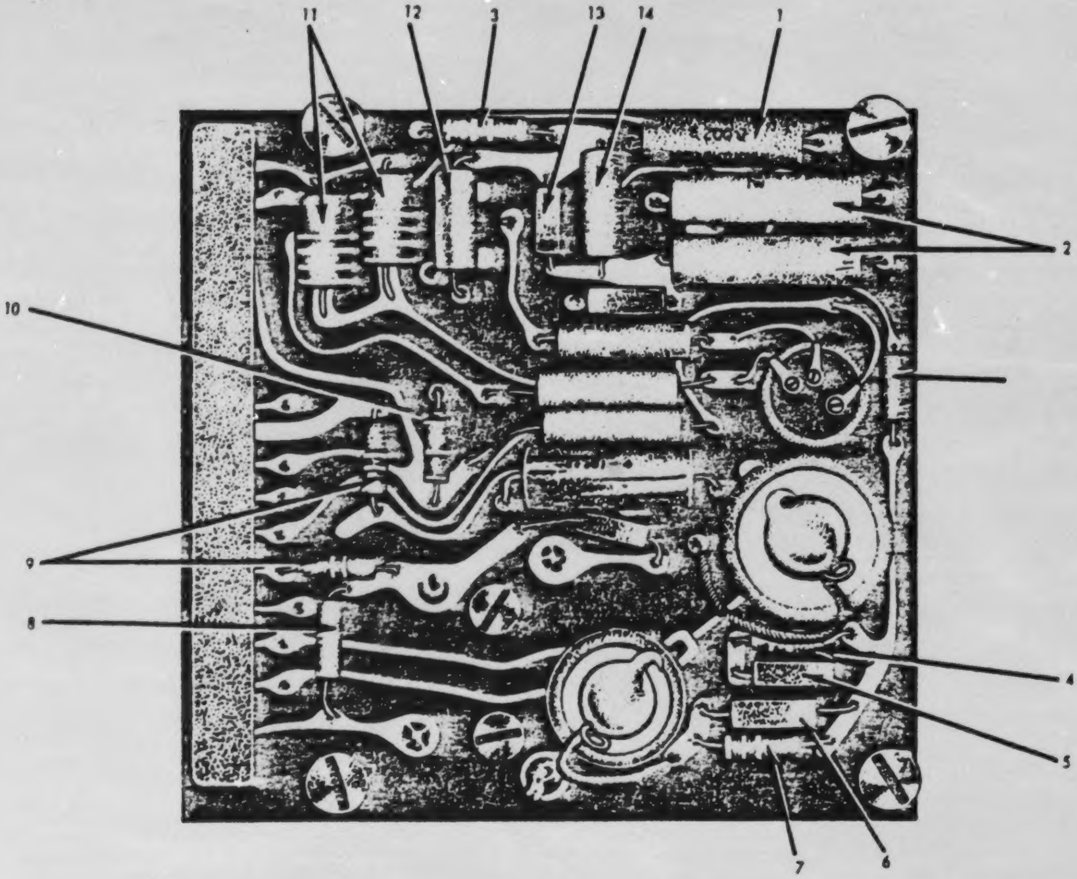
8–RESISTANCE VALUES ARE SHOWN BELOW THE LINE, VOLTAGES ABOVE THE LINE.

Figure 16. Voltage and resistance measurements.

Begin by eliminating as many components or circuits as your observations have shown to be operating properly. Some parts can be eliminated by the symptoms alone, while elimination of others may call for the use of test equipment. Regardless of the methods used, every part eliminated brings you closer to the source of the trouble.

7-28. You will find troubleshooting analysis charts in your equipment technical manuals. These cover the malfunctions that have been found to occur over and over again in that equipment. In addition to these common troubles that have been covered in the troubleshooting charts, you will find many troubles peculiar to the specific set (or system) on which you are working. The unusual problems force you to use your information resources and your experience to solve them. Every malfunction requires a thorough analysis as a part of the troubleshooting procedure. This is a challenge you must be prepared to accept; only on your own initiative can you succeed. We have described some of the resources you can use in your analysis. In addition to using these resources, you must know how to use the test equipment.

7-29. You must be able to recognize any symptoms of troubles (detected through routine checks or as reported). Failure to do so may result in the loss of many man-hours. Without intensive observation of equipment, the first indications of trouble may be overlooked. Many troubles can be spotted through indicator presentations, equipment meter readings, and performance reports. Some troubles such as low receiver sensitivity, however, are not readily apparent and must be detected by periodic per-



1	CP05A3KC104K	CAPACITOR, FIXED, PAPER DIELECTRIC (MIL-C-25A)	1
2	RE1304-17	RESISTOR, FIXED, FILM, 56,000 OHMS 1%, 1 W	2
3	RC20GF101J	RESISTOR, FIXED, COMPOSITION (MIL-R-11C)	2
4	RC20GF203J	RESISTOR, FIXED, COMPOSITION (MIL-R-11C)	1
5	CM15C750J	CAPACITOR, FIXED, MICA DIELECTRIC (MIL-C-5A)	1
6	CM15B150K	CAPACITOR, FIXED, MICA DIELECTRIC (MIL-C-5A)	2
7	RC20GF633J	RESISTOR, FIXED, COMPOSITION (MIL-R-11C)	1
8	RC20GF223J	RESISTOR, FIXED, COMPOSITION (MIL-R-11C)	2
9	RC20GF362J	RESISTOR, FIXED, COMPOSITION (MIL-R-11C)	1
10	RC42GF683J	RESISTOR, FIXED, COMPOSITION (MIL-R-11C)	2
11	RE1304-10	RESISTOR, FIXED, FILM, 270,000 OHMS 1%, 1 2 W	1
12	CM15B100K	CAPACITOR, FIXED, MICA DIELECTRIC (MIL-C-5A)	1
13	RE1304-21	RESISTOR, FIXED, FILM, 620,000 OHMS 1%, 1 2 W	1
14	CM15C331J	CAPACITOR, FIXED, MICA DIELECTRIC (MIL-C-5A)	1

Figure 17. Component illustration.

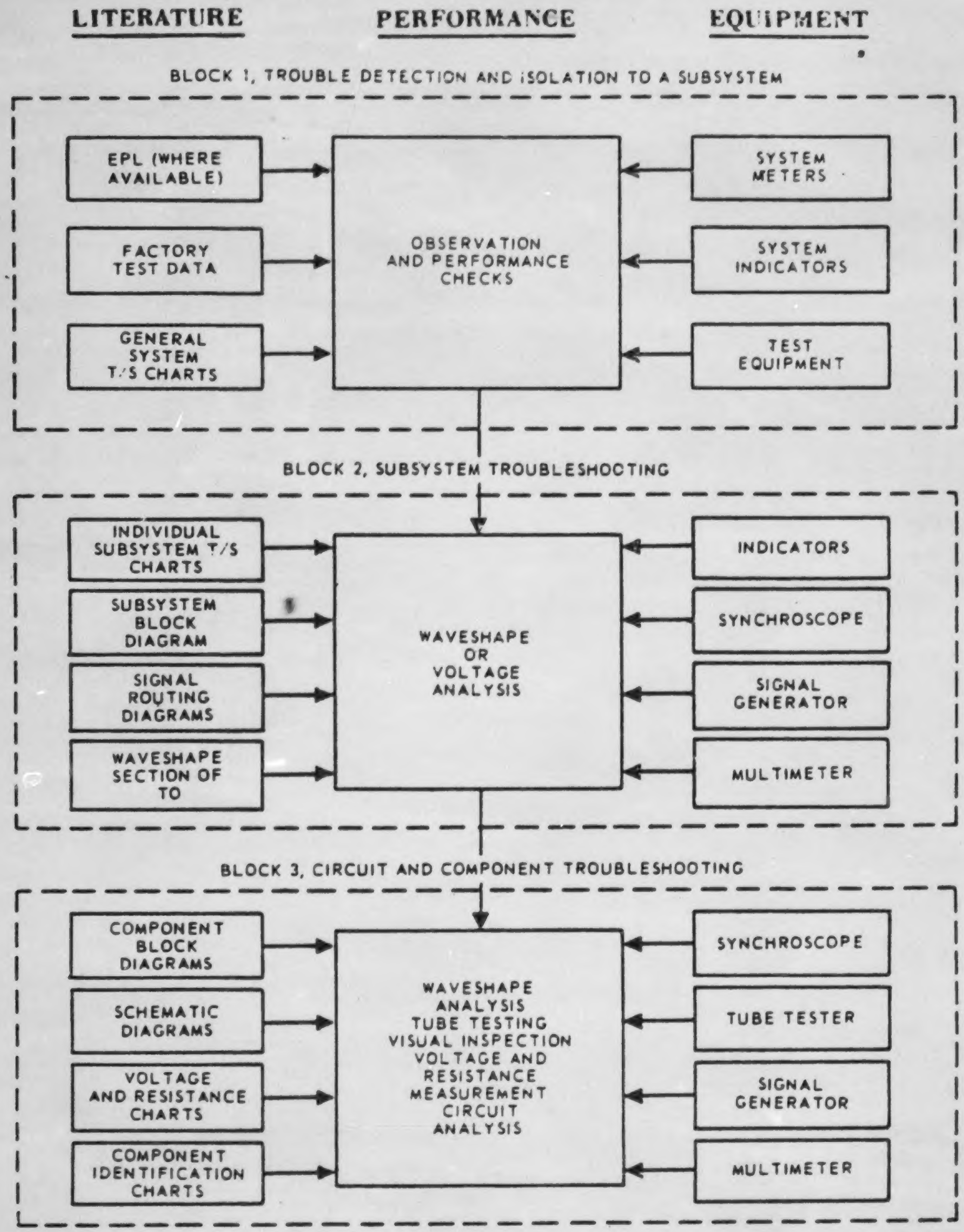

LITERATURE
PERFORMANCE
EQUIPMENT
BLOCK 1, TROUBLE DETECTION AND ISOLATION TO A SUBSYSTEM
EPL (WHERE AVAILABLE)
FACTORY TEST DATA
GENERAL SYSTEM T/S CHARTS
OBSERVATION AND PERFORMANCE CHECKS
SYSTEM METERS
SYSTEM INDICATORS
TEST EQUIPMENT
BLOCK 2, SUBSYSTEM TROUBLESHOOTING
INDIVIDUAL SUBSYSTEM T/S CHARTS
SUBSYSTEM BLOCK DIAGRAM
SIGNAL ROUTING DIAGRAMS
WAVESHAPE SECTION OF TO
WAVESHAPE OR VOLTAGE ANALYSIS
INDICATORS
SYNCHROSCOPE
SIGNAL GENERATOR
MULTIMETER
BLOCK 3, CIRCUIT AND COMPONENT TROUBLESHOOTING
COMPONENT BLOCK DIAGRAMS
SCHEMATIC DIAGRAMS
VOLTAGE AND RESISTANCE CHARTS
COMPONENT IDENTIFICATION CHARTS
WAVESHAPE ANALYSIS TUBE TESTING VISUAL INSPECTION VOLTAGE AND RESISTANCE MEASUREMENT CIRCUIT ANALYSIS
SYNCHROSCOPE
TUBE TESTER
SIGNAL GENERATOR
MULTIMETER

Figure 18. Troubleshooting chart.

formance checks. To minimize downtime (inoperative period), you must develop a system of troubleshooting. This should include examination of all available equipment records, evaluation of operator's comments, and performance of operational checks when possible.

7-30. Locating the trouble is usually the most difficult step in corrective maintenance and is therefore the one to which we give the most emphasis. A mechanic's troubleshooting technique is based on his knowledge of the operational standards and diagrams of the equipment. So, as part of the technique, you must be able to read and understand technical literature, such as cabling charts, schematics, block diagrams, and voltage and resistance charts.

7-31. The troubleshooting chart, shown in figure 18, illustrates the proper troubleshooting principles. This chart will help you develop a systematic method of troubleshooting. First, by observation and by making performance checks, you eliminate all the subsystems which are functioning properly. Next, by further analysis, isolate the trouble to a subsystem. Then trace or isolate the trouble to a circuit, and from there to a specific part or parts. This is done through further analysis, visual inspections, tube testing, waveshape and voltage measurements, and finally, resistance measurements. Some of the necessary literature and test equipment required are shown in the chart.

7-32. Figure 18 shows that the first step of troubleshooting is *trouble detection and isolation to a subsystem*. To do this, you must understand the performance standards, know how the equipment is operating, and be able to recognize symptoms.

7-33. Having located the trouble in a particular subsystem, you are now ready to isolate the trouble within that portion of the equipment. The subsystem may consist of many units or components. In the next step (block 2 of fig. 18), you localize the trouble to a major subgroup or unit.

7-34. Isolation of the specific circuit begins after you have localized the trouble to a unit. A common technique of isolating the trouble is the half-split method. You can apply this technique to almost any situation. The object is to isolate the defective stage as rapidly as possible. We will use the block diagram of an electronic system in figure 19 to illustrate this practice.

7-35. Stage 1 is the signal source, and the output is taken from stage 8. If the indicated trouble is no signal output, the first point to check would be point D. This checkpoint is located at the center of the chain. If the signal is present in the output when the appropriate signal is injected at point D, stages 5 through 8 are therefore eliminated. The second checkpoint is B. This usually divides the remaining section. If no signal is in the output when the signal is injected at this point, the trouble is isolated to stage 3 or 4. When the trouble has been isolated to one stage, check the components there, using the schematic diagrams. Had there been no output when the proper signal was injected at point D, the trouble would have been somewhere between stage 5 and the output.

7-36. An oscilloscope, multimeter, or signal substitution is generally used to isolate the trouble to one stage. If a tube is involved, it is usually checked first, or a tube known to be good is substituted in its place. If the tube proves to be good, additional checks are made, using an oscilloscope or voltohmmeter.

7-37. To aid in these final checks, technical manual references should be used. In some cases a schematic is all that is necessary; in others, voltage charts, resistance chart, or waveforms may be needed. However, there is no substitute for good, logical thinking. The important things to remember are:

- Use your block diagram.
- Narrow the trouble down as far as possible with indications from the equipment itself.
- Look for the most common troubles (bad tubes) first.

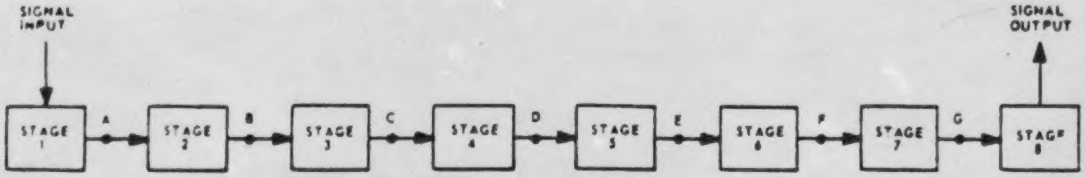


Figure 19. Typical half-split method of troubleshooting.

- In most cases, check voltages or waveshapes before measuring resistance.
- Most important, think it out and analyze the symptoms carefully before removing components. A little effort in this direction can save a lot of time and labor.
- Check your records. Do not overlook the importance of your fellow worker's previous experience. This same trouble could have happened to him.

7-38. **General Repair.** Since each repair is an individual problem and differs from the previous one in some respect, it is almost impossible to set up a routine or a production-line technique and adhere to it. There are certain principles, however, that should be followed in all cases if you are to complete the repair with the least amount of time and expenditure of parts. Let's discuss two of the principles that apply to general repair.

7-39. *Look phase.* When a piece of equipment needs repair, clean it first. Remove all foreign matter and dry the equipment thoroughly. By reviewing the section on preventive maintenance in this chapter, you will become more familiar with the methods of cleaning electronic equipment.

7-40. Since operating symptoms usually indicate the source of trouble, understanding them shortens your work in repairing the equipment. Such symptoms should be described on the AFTO Form 349 or 350, which is placed on the equipment by the repairman. These forms will be discussed in the next section of this manual.

7-41. Before you start the actual repair, give the equipment a thorough visual check and replace all of the damaged parts. This will simplify your work. If this is a piece of equipment that you know well, you may easily spot defects during the visual check.

7-42. *Replacement of parts.* A replacement part should occupy the same position as did the original, and should be an exact duplicate of the old part. When a part is to be replaced, it is necessary to check the reference symbol in the schematic and the illustrated parts breakdown technical manual. The illustrated parts breakdown technical manual contains information you need to order the parts.

7-43. When an exact replacement is not available, however, use a part which is in accordance with the description of the original in the maintenance parts list or the appropriate stock catalog. Even though a part may have the same electrical value as the original, if it differs in physical size, it may cause trouble in high-frequency circuits.

7-44. In replacing parts, use the same ground point as did the original wiring. Before unsoldering a part, note the position of the leads. If the part (such as a transformer) is to be removed, tag each of the leads. In addition, you should draw a simple circuit diagram before you remove any parts. Be careful not to damage other leads or components by pulling, pushing, or burning them.

7-45. **Circuit Alignment.** It should be clear that it is impossible (or very impractical) to manufacture electronic components with no variations at all in the values. And, of course, you also understand that aging of parts, climatic conditions, vibrations, etc., may cause the values of components to change. Because of this, variable components are provided in some tuned circuits that require circuit alignment. Thus, by a slight retuning or adjustment from time to time, the optimum performance specified in the maintenance manuals or by the manufacturer may be attained.

7-46. Reduced sensitivity or reduced output may indicate a need for alignment; however, alignment should not be undertaken until the equipment has otherwise been checked out. Every piece of equipment that is operating poorly requires maintenance, but it does not follow that every piece of equipment that needs maintenance also needs alignment. However, repairs that require the replacement of components or the redressing of wiring may make subsequent alignment necessary. Therefore, you should not attempt alignment until all troubles have been cleared and all defective parts replaced. It cannot be stressed too highly that *before* alignment is attempted, all available instructional or maintenance literature should be carefully consulted.

7-47. **Performance Testing.** A performance test is a check made to determine the condition or the operating efficiency of the equipment. The first checks are performed when the equipment is initially installed. Such checks will continue to be performed periodically (at the beginning of each shift, for example), at the conclusion of either preventive or corrective maintenance, and at any other time there is reason to believe the equipment is operating below accepted standards. At these times it is necessary that you check the equipment against the indicated performance standards in the technical manual, using the proper test equipment. While these checks do reveal improper or defective operating circuitry, in many cases a simple adjustment will correct the malfunction.

8. Repair of Printed Circuits and Transistor Replacement

8-1. The printed circuit assembly is a comparatively recent development in the electronic field. Printed circuits have replaced conventionally wired circuits in practically all applications.

8-2. Printed circuits are easy to troubleshoot, since all leads can easily be seen and the circuit components are readily accessible. Generally, the measurements of components can be made from the component side of the board.

8-3. This section deals with the general repair of printed circuits and not with specific equipment. Before you begin repair of printed circuity in specific equipment, read the applicable technical manuals. The quality control directives pertinent to a particular system will also govern methods of repair as you will see in the next section.

8-4. **Types of Printed Circuits.** A true printed circuit is a pattern comprising printed wiring and printed component parts, all formed in a predetermined pattern. There are several types of printed circuits, some of which are listed below.

- Chemically deposited. Formed by the reaction of chemicals in an applied electrical field.
- Embossed foil. Formed by indenting a metal foil into an insulating base and removing the unwanted raised portion.
- Etched. Formed by chemical or chemical and electrolytic action, and removal of the unwanted conductive material.

These printed circuits mentioned are only a few of many. We shall not try to explain all of them.

8-5. **Precautions.** Printed-circuit bases, made from fiberglass laminates or some other plastic materials, are delicate in comparison to metal chassis and must be handled accordingly. Some precautions are:

- Be careful in removing and installing printed-circuit assemblies.
- Carefully remove separable component parts. Undue flexing may break the conductive pattern.
- Avoid excessive deposits of solder which may cause short circuits.
- Use the least amount of heat possible for conductor repair.
- Always use a heat sink for removal and replacement of components.
- Use small tools and handle them properly.

8-6. **Circuit Tracing.** Circuit tracing of the printed-circuit assembly is generally simpler than that of conventional wiring, because of the uniform layout of the conductors in a printed-circuit assembly. Printed-circuit assemblies have the path of the conductive pattern painted opposite the component side. Here, on this opposite side, the component is marked with the schematic symbol to aid in troubleshooting. The latest assemblies have test points with the appropriate voltage readings indicated. Some bases are translucent, and a 60-watt lamp placed opposite the side being traced will help you to locate connections.

8-7. Tube socket test adapters may be used to measure the voltage while the equipment is in operation. The adapters let you get to each pin socket without damaging the printed circuit circuitry.

8-8. Resistance or continuity measurements of coils, resistors, and capacitors can be made from the component side of the assembly. The voltage measurements can be made on either side of the panel, but on the conductor side, a needlepoint probe should be used.

8-9. **Removal and Replacement of Components.** The removal and replacement of defective components on a printed-circuit board is not difficult, but it does require a certain amount of care because of the fragile construction of the board. Misuse of a soldering iron or the use of improper handtools can result in the need for complete replacement of a printed-circuit component repairs involve the removal and replacement of resistors and capacitors.

8-10. *How components are mounted.* Components may be mounted on printed-circuit boards in the following ways. Each type of mounting may require slightly different techniques in the removal.

- The component lead is cold formed into a tapered pin that is pressed into a plated hole and soldered.
- A tapered wrap is swaged to the component lead and then inserted.
- The bare component lead is passed through an eyelet and soldered.
- Cold wire wrap secures component to the terminal pins.

8-11. *Recommended tools.* The tools used to repair metal chassis are not practical in the repair of printed circuits. Printed circuits are small and should be repaired only with small tools. Although many diversified tools might be used for the various special jobs, here is a list of those tools most frequently used.

- Printed circuit board repair vise.
- Heat sink.
- Long-nose pliers.
- Soldering aid with forked end.

- 37-watt soldering iron with iron-clad tip.
- Stiff wire brush.
- Diagonal cutters.
- Cleaning solvent.
- 60/40 solder.
- Wiping cloth.
- Solder sucker (coaxial-type braid soaked in liquid resin).

8-12. *Troubleshooting and repair aids.* There are many things that may aid you in the troubleshooting and repair of printed circuits. The most important "aid" is to practice good common sense. The following items will help you in the repair of printed circuits.

- Magnifying glass. Aids in locating very small breaks in the conductors.
- Needlepoint probe. An aid in measurements, since the varnish coating on the circuit must be broken through if you are to make proper contact.
- Light. Facilitates circuit tracing if the board is translucent.
- Silicone resin varnish. Repaired areas should be cleaned and then recoated with silicone resin varnish for protection against shorts.

8-13. *Service terminal component replacement.* Replacement of resistors and capacitors may be done in either of two ways. The faulty component can be cut away from the board and the leads remaining on the board can be reshaped for use as soldering terminals for the new component. In the second method the defective component and its leads are completely removed from the board and the new component soldered into its place on the board. The first method is more commonly used because it is easier to do under normal maintenance conditions and offers less chance of heat damage.

8-14. The steps in repairing printed circuits in this manner are listed below and shown in figure 20.

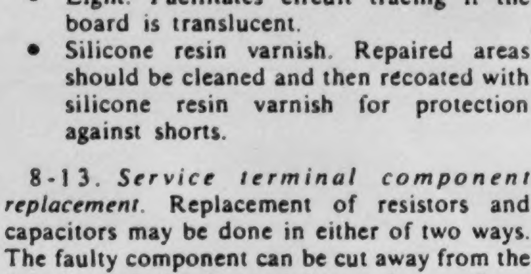


Figure 20. Service terminal method.

- Remove the defective component by clipping the lead 3/16 of an inch from the top of the terminal wrap.
- Straighten the ends of the clipped leads.
- Clean each lead.
- Slide the service terminal lug (as shown in fig. 20, detail A) over the clipped lead. The tip of the clipped lead must be flush with the top of the service terminal. Clip off any excess lead material and crimp (squeeze) the service terminal lug to the clipped lead.
- Cut the new component leads to length so that the tip of the lead is at least flush with the service terminal lug to be crimped, as indicated in figure 20, detail B.
- If the component is a solid-state device or precision resistor, a heat sink, similar to the one shown in figure 21, must be used.
- Solder the service terminal lug with a suitable well-tinned iron and a minimum amount of solder.

8-15. CAUTION. Care must be used to avoid applying heat to the printed-circuit board or the component.

8-16. In reattaching a component that has been clipped on one end only, the service terminal lug should be rotated 180°.

8-17. *Complete component replacement.* This second method of removal and replacement of defective components is more difficult than the first; it requires more precise work, but it is a neater and more effective method. The complete removal and replacement of a defective component is usually done by depot level maintenance personnel. Listed below are the more important steps for complete replacement of a defective component.

(1) Secure the printed circuit board in a test jig or vise type of gripping holder.

(2) Grasp the lead on one end of the defective component with the forked end of the soldering aid. This should be done as close to the component's body as possible. If you have any doubts as to whether or not the component is defective, place a heat sink on the lead as close to the component as possible.

(3) Apply the soldering iron to the component lead (on the side of the heat sink away from the component), being especially careful not to acutually touch the eyelet through which the lead is soldered.

(4) When the solder within the eyelet begins to flow, use a gentle lifting motion with the soldering aid or heat sink to remove the component lead from the eyelet.

(5) Repeat the preceding steps on the other lead of the component. Clean both eyelets; be sure to remove all traces of resin.

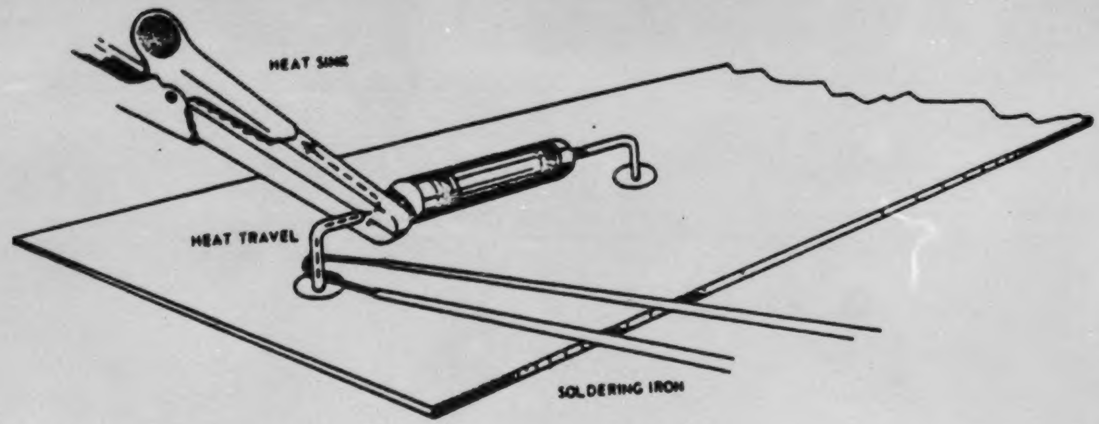


Figure 21. Heat sink.

(6) Shape the leads of the new component to match those of the faulty component just removed. Insert the component leads into the eyelet.

(7) Hold the new component with a pair of long-nose pliers (or use a heat sink) to protect the component. Apply the soldering iron to the component lead and allow solder to run into the eyelet.

(8) Turn the board over and make sure the soldered connection is secure. There should be a small solder bead formed. Be sure to do all soldering operations in as little time as possible, since excessive heating causes the printed wiring to tear loose from the phenolic.

(9) Repeat the two previous steps to secure the other lead.

8-18. NOTE: When using the long-nose pliers as a heat sink, wrapping a rubber band around the handles to hold them closed around the component lead makes it possible for you to use both hands in soldering.

8-19. **Wire Wrap Connections.** There are many different types of wire connections that you will be required to make. It is beyond the scope of this course to show all the types, but we will show you some of the more commonly used wire wraps.

8-20. *Eyelet terminal wire wraps.* To replace a wire lead into an eyelet, use the following procedure:

(1) Strip and tin leads to be connected.

(2) Insert lead into eyelet (see fig. 22).

(3) Wrap the lead around the terminal and crimp it to provide a good electrical connection. Several satisfactory wraps are shown in figure 22, detail A.

8-21. *Terminal wire wraps.* These are much the same as eyelet connections, except that the wire is wrapped around a turret. To use this type of wrap, follow this procedure:

- Strip and tin the leads to be connected.
- Wrap the lead around the terminal turrent as shown in figure 22, detail B. Make at least one and not more than two complete turns around the terminal. NOTE: Jumper leads are connected to the lower portion of the terminal while the components are connected to the upper portion.
- Solder the lead to the terminal.

8-22. *Old lead wrap.* When replacing a defective component and using the remains of the old leads as connections, clean the old lead wire wrap to provide a good electrical connection. The following procedure is the best.

- Remove the defective component by clipping the lead approximately 1/8 inch from the component body.
- Straighten the leads remaining on the board.
- Clean the leads to assure a good connection.
- With needle-nose pliers, bend into loops the leads remaining on the board.
- Insert the leads of the new component as shown in figure 22, detail C, and solder the connection.

8-23. *New component wrap.* The new component wrap method is much the same as that shown in figure 22, detail C. The following steps result in a good electrical connection when you are installing the new component:

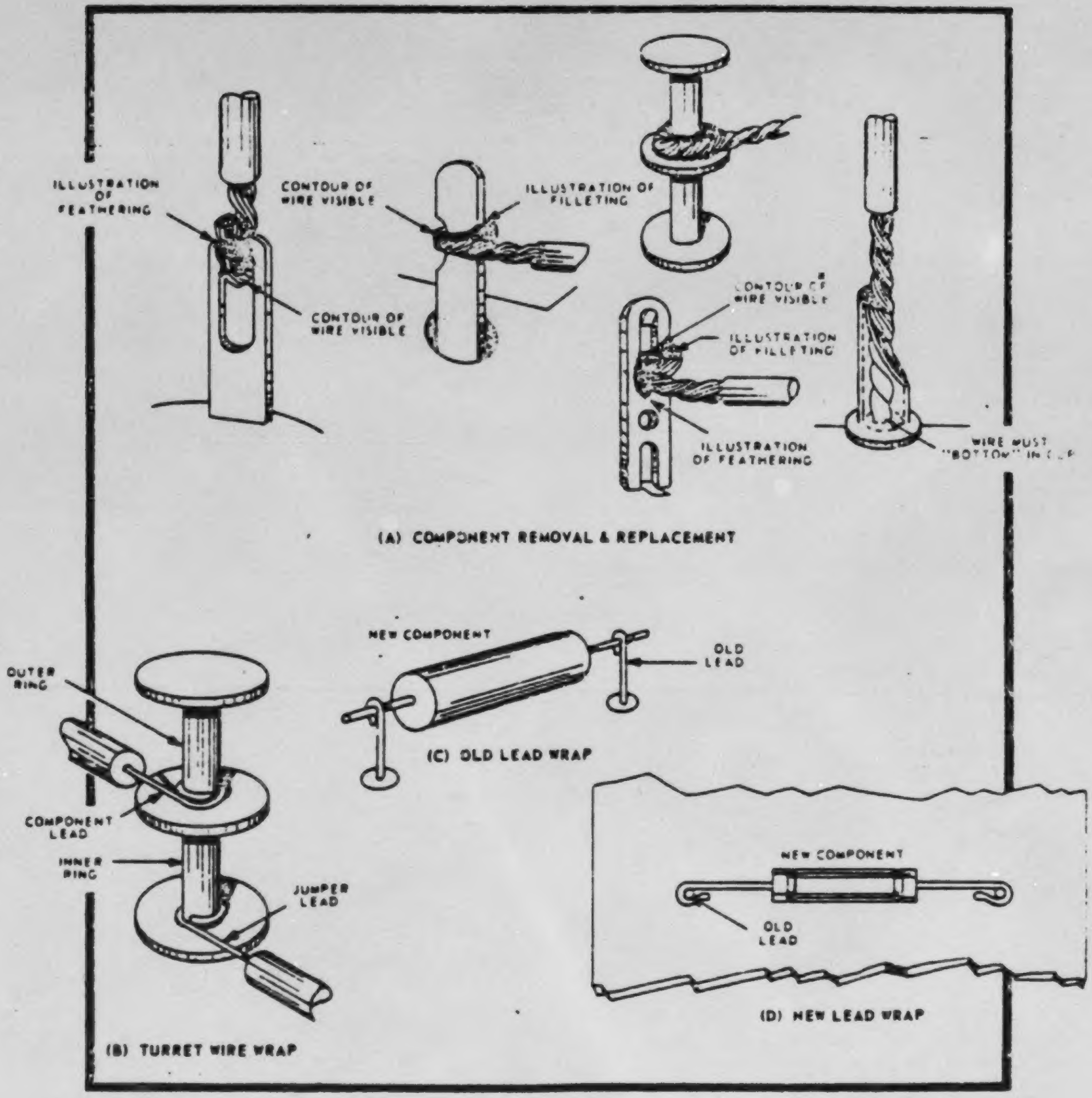


ILLUSTRATION OF FEATHERING
CONTOUR OF WIRE VISIBLE
CONTOUR OF WIRE VISIBLE
ILLUSTRATION OF FILLETING
CONTOUR OF WIRE VISIBLE
ILLUSTRATION OF FILLETING
ILLUSTRATION OF FEATHERING
WIRE MUST "BOTTOM" IN CUP
(A) COMPONENT REMOVAL & REPLACEMENT
NEW COMPONENT
OLD LEAD
(C) OLD LEAD WRAP
OUTER RING
COMPONENT LEAD
INNER RING
JUMPER LEAD
(B) TURRET WIRE WRAP
NEW COMPONENT
OLD LEAD
(D) NEW LEAD WRAP

Figure 22. Wire wrap connections.

(1) Remove the defective component by clipping the leads 1/8 inch from the old component body.

(2) Straighten the leads remaining on the board.

(3) Clean the leads to assure a good connection.

(4) Center the new component between the clipped leads and wrap the component leads around the clipped leads as shown in figure 22, detail D.

(5) Crimp the component lead to the clipped lead to provide a good connection. Remove excess wire.

(6) Solder the new connection.

8-24. **Repair of Printed-Circuit Boards.** Cracks and crazes (surface separations that do not extend completely through the body of the board) are considered for repair only if all the following conditions are met: (1) The crack must not run under, or appear to run under, a conductor on either side of the board. (2) No single crack can be more than 5/8 inch in length. (3) there will be no more than two reparable cracks on a board. (4) no cracks may originate at either of the mounting edges or from the other edges of the board to within 1 inch of either mounting edge. (5) No cracks may extend in a line parallel to the mounting edge of the board. If the printed-circuit boards are not damaged to a point beyond repair, they should be fixed. A crack in the base can allow moisture to collect and form unwanted conductive paths between the conductors. To prevent this, the cracks must be sealed. This can be done by using an epoxy-resin compound applied as follows:

- Secure board so that it will be held steady. Use proper size equipment.
- Drill a small hole at each end of the crack. This prevents the crack from extending.
- Open the crack on both sides of the base material, using a saw, a gouging tool, or a knife to a depth sufficient to receive the epoxy-resin.
- Clean the open crack and the surrounding area with an approved solvent or by scraping with a knife.
- Apply the ready-mixed epoxy-resin compound and allow the air to cure it for approximately 24 hours.
- Reclean the surface and varnish the repaired area.

8-25. In addition to the repair of cracked printed-circuit boards, you should have some idea of how to repair raised foil when it is damaged beyond serviceable condition. Remember to handle printed-circuit assemblies carefully and to use a low-wattage soldering iron and low-temperature solder.

8-26. There are two methods that can be used in the repair, depending upon the size of the damaged area. If the break is small, as shown in figure 23, details A and B, in both sides of the break, then flow solder across the open area.

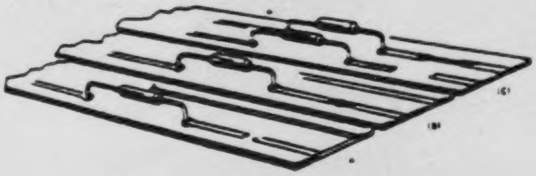


Figure 23. Open conductors.

8-27. Figure 23, detail C, shows a larger break in the foil. Tin both sides of the break; lay a piece of solid hook-up wire across the opening and solder it to each side of the break. Bare wire may be used if the break is not too large.

8-28. In some instances where the break is large, it may be more feasible to "jump" the damaged area. This may be done by installing a wire from one component eyelet to the next in series.

8-29. If the printed circuit foil becomes raised from the board as shown in figure 24, clip off the raised section. The repair of the clipped-off foil then would be the same as repairing an open conductor, as shown infigure 23, details B and C, depending on how large the raised area is.

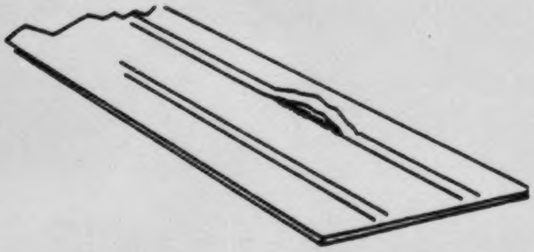


Figure 24. Raised foil repair.

8-30. **Transistor Replacement.** Special emphasis should be placed on our discussion regarding replacement of transistors. In many instances, these components are mounted very close to the printed-circuit board. This closeness in itself makes a difficult situation, which is compounded by the fact that the transistor can be damaged by the application of excessive heat. In view of this, special precautions must be taken when a transistor must be replaced. Some transistors have socket connections much like a regular vacuum tube which, of course, makes the replacement very simple. However, the type that is most commonly used must be soldered in place. The following procedures outline the methods for replacing transistors:

- Secure the assembly holding the transistor in a test jig or a vise.
- Cut away the transistor body as shown in figure 25.

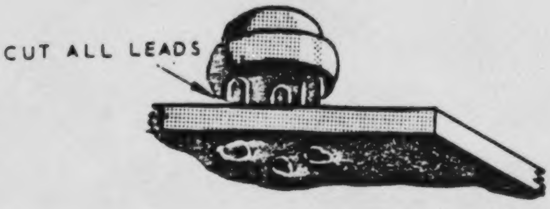


Figure 25. Transistor replacement.

- Heat the remaining leads and when they are loose, pull them out.
- Clean the excess solder from the eyelets.
- Shape the leads of the replacement to conform with the faulty component. Insert the new transistor.

- Grasp the lead as close to the transistor body as possible with a pair of long-nose pliers. The pliers will function as a heat sink as well as hold the transistor in place.
- Flow solder into the eyelet. Repeat this step until all leads are securely fastened. When replacing a transistor, it must be remembered that excessive heat will damage the transistor.

9. Cable Maintenance

9-1. Occasionally, you will fabricate cables for electronic equipment. It will be your responsibility to insure that they are correctly made and checked. An improperly constructed cable may cause a piece of equipment to be inoperative, prevent it from taking part in a strategic mission, and even cost the lives of Air Force personnel. It is well, therefore, that we discuss here the proper procedures for constructing, checking and repairing cables.

9-2. The material used in cable construction should meet all the specifications in the equipment technical manual or the authorization for the particular installation.

9-3. Cable lengths, of course, depend on the placement of the units. The various cables required, their use, and their length limitations are usually described in the equipment technical manual or in the installation directives. In most cases, high-voltage cables are fabricated at the factory. The materials necessary for other cables, supplied in bulk, consist of the wire to be used and the cable covering. Normally the fittings for terminating these cables are supplied with the bulk material. Vinyl plastic cable covering is the most common covering in use at the present time.

9-4. Cables should be made long enough so there is sufficient slack for connecting and disconnecting the plugs from their receptacles. If the cable lengths are not specified, you may have to tailor them to fit the installation after the units have been installed.

9-5. **Multiconductor Cables.** Multiconductor cables vary from those having two leads to those having many leads. In this type of cable several different wire sizes may be required, depending on the amount of current each must carry. The amount of insulation required on any lead is determined by the potential that exists along the lead. For extremely high voltages, a special high-voltage cable is used. The exact specifications for all multiconductor cables may be found in the appropriate technical manual on the equipment.

9-6. **Coaxial Cable.** Most electronic systems use coaxial cable and connectors. Figure 26 shows an example of a coaxial cable and the assembly of the connectors. When handling or working near coaxial cables, observe the following precautions:

- Never bend a coaxial cable sharply because of its special construction.
- Check to insure that the bend radius is at least six times the diameter of the cable.
- Do not use spot ties unless specified.
- Use only cushion-type clamps. The clamps must not fit around the cable tightly.
- Always allow some slack between mounted equipment and the first clamp.
- Carefully inspect a coaxial cable for cuts, flat spots, and other evidence of abuse before installing.

9-7. **Cable Identification.** Generally, electronic equipment (to facilitate the installation and troubleshooting of wiring) will have the wiring and coaxial cables identified by a letter/number combination. The letter/number identification is stamped directly on the wire or on sleeving attached to it. On standard wiring the identification number is stamped on the wire at 15-inch intervals and within 3 inches of each break and terminating point. Wires from 3 to 7 inches in length are stamped near the center only; wires less than 3 inches in length are not identified. Wiring identifications are stamped in black—except AC wires which are stamped in red. Coaxial cables, multiconductor cables, multiconductor cables, unjacketed shielded cables, wires which do not retain a machine-imprinted identification, and wires with a rough surface which do not take a clear imprint are identified by sleeving at the ends only. In any case, all equipment wiring will have some form of identification. For specific information on wiring identification, refer to the equipment technical order.

9-8. **Safety Wiring.** Electrical connectors, emergency devices, and some electronic equipment are secured with safety wire, where specified in appropriate directives, to prevent injury to people and equipment. For securing coupling parts of AN connectors, use corrosion-resisting steel lock wire. (Use .032-inch lock wire whenever possible.) For securing emergency devices where it may be necessary to break the wire quickly, use aluminum or copper wire. Zinc-coated carbon steel wire is used in locations where the wire may come into contact with magnesium. Only new wire should be used when securing equipment. Do not attempt to reuse old safety wire on any item that requires replacement.

9-9. Two principles of safety wiring are illustrated in figure 27. The double twist

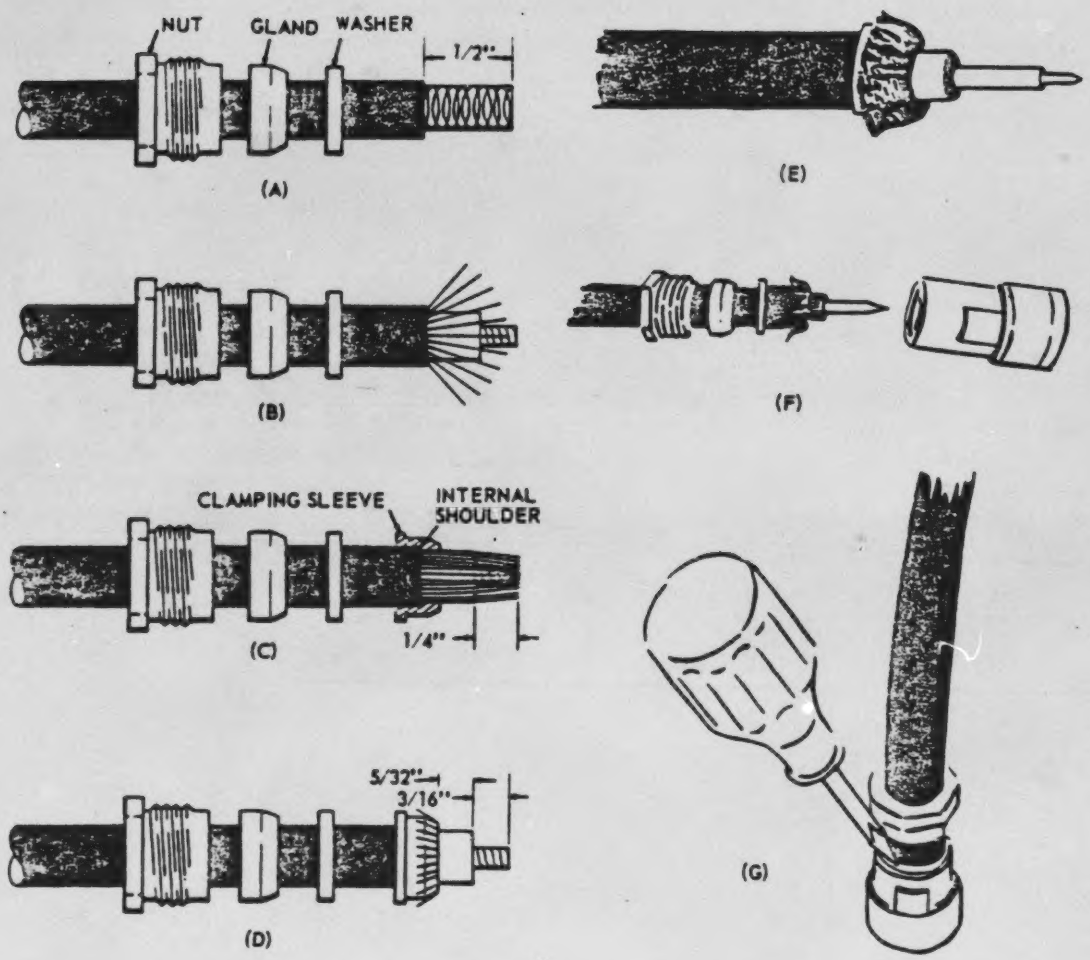


Figure 26. Coaxial cable and connector.

method, shown in figure 27, detail A, should be used whenever possible. The single wire method, shown in figure 27, detail B, should be used in only the following cases:

- For emergency devices.
- For safety wiring in areas difficult to reach
- For small screws in a closely spaced pattern, as illustrated in figure 27, detail B.

9-10. **Bonding and Grounding.** The principles to be followed in the preparation and installation of bonding and ground connections are as follows: Bonding and grounding connections (1) protect the equipment and personnel from lightning discharge and electrical shock, (2) prevent development of RF potentials, and (3) provide current-return paths. When making bonding or grounding connections, observe the following precautions and principles.

- Bond or ground parts to the primary structure (main frame) where practicable.
- Make bonding or ground connections in such a way as not to weaken any part of the equipment structure.
- Bond parts individually whenever possible.
- Make bonding or grounding connections against smooth, clean surfaces.
- Install bonding or grounding connections so that vibration, expansion, contraction, or movement incident to normal use will not break or loosen the connection.
- Whenever possible, locate bonding and grounding connections in protected areas near holes, inspection doors, or other accessible

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MODIFICATIONS

Pages 40-50 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

CHAPTER 4

Oscilloscopes and Test Accessories

FROM YOUR training and experience, you know how useful the oscilloscope and synchroscope are for observing waveforms. The pictorial presentation of waveforms makes it possible to analyze the operation of many electronic (and some mechanical) systems. Malfunctions can usually be pinpointed by waveform inspections. You know also that these instruments can be used to make measurements of current, voltage, and frequency. On the basis of such facts, it is apparent that oscilloscopes and synchroscopes are test equipments of utmost importance to you and are, therefore, worthy of study.

2. In this chapter we describe the makeup of oscilloscopes and synchroscopes. Much of the discussion about their operation is, no doubt, a review for you. Our coverage is sufficiently complete to insure your understanding the functions and capabilities of these test equipments so that you can be sure that they are properly used. Circuit analysis is unnecessary, since most of the circuits within oscilloscopes and synchroscopes are conventional ones that you should know. Specialized circuits may differ considerably in design because of differences between manufacturers, but—*functionally*—they are similar. Therefore, we will stress *functions* rather than *circuits*.

12. Functional Analysis of Oscilloscopes

12-1. The basic oscilloscope (fig. 30) includes a cathode-ray tube, a sweep generator, horizontal and vertical deflection amplifiers, and power supplies. The *synchroscope* (see fig. 31) is a sophisticated oscilloscope which is widely used in maintenance procedures. It contains special circuits which provide additional capabilities. The signal channel of the synchroscope contains frequency-compensating circuits which permit a much wider frequency range than is provided by the

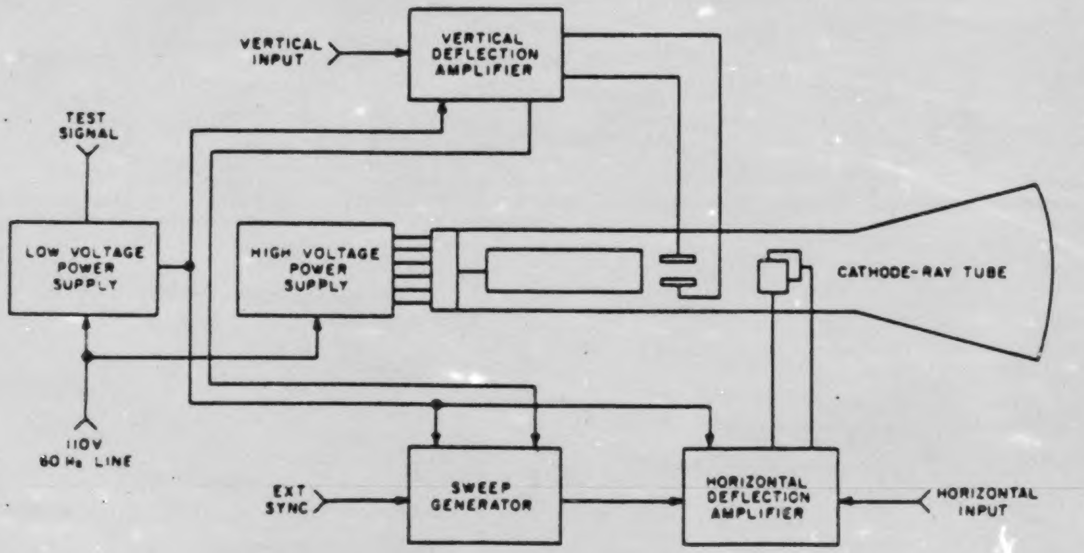

VERTICAL INPUT
VERTICAL DEFLECTION AMPLIFIER
TEST SIGNAL
LOW VOLTAGE POWER SUPPLY
HIGH VOLTAGE POWER SUPPLY
CATHODE-RAY TUBE
110V 60 Hz LINE
EXT SYNC
SWEEP GENERATOR
HORIZONTAL DEFLECTION AMPLIFIER
HORIZONTAL INPUT

Figure 30. Basic oscilloscope.

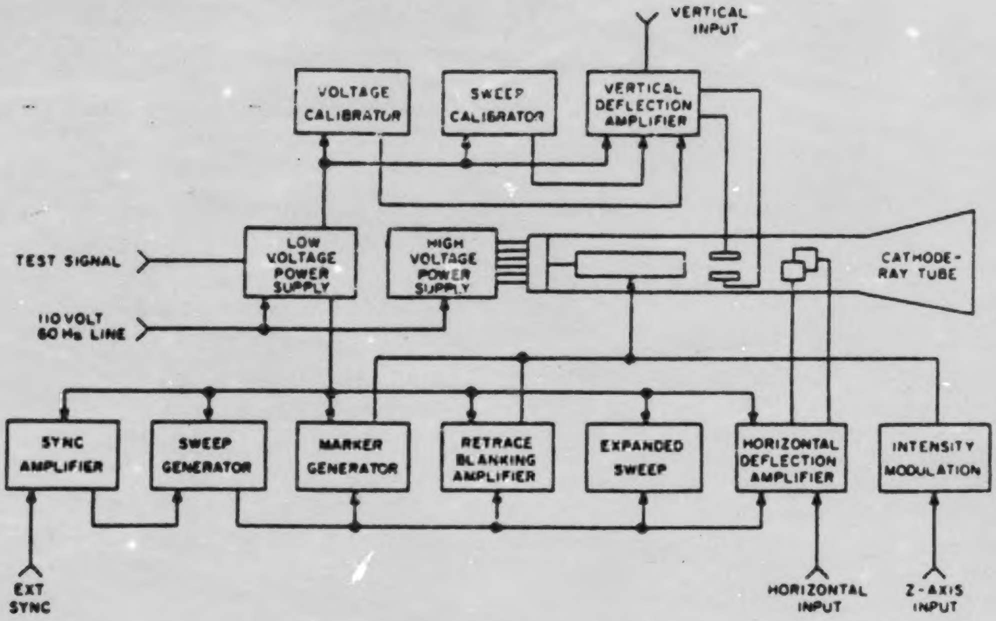

VERTICAL INPUT
VOLTAGE CALIBRATOR
SWEEP CALIBRATOR
VERTICAL DEFLECTION AMPLIFIER
TEST SIGNAL
LOW VOLTAGE POWER SUPPLY
HIGH VOLTAGE POWER SUPPLY
CATHODE-RAY TUBE
110 VOLT 60 Hz LINE
SYNC AMPLIFIER
SWEEP GENERATOR
MARKER GENERATOR
RETRACE BLANKING AMPLIFIER
EXPANDED SWEEP
HORIZONTAL DEFLECTION AMPLIFIER
INTENSITY MODULATION
EXT SYNC
HORIZONTAL INPUT
Z-AXIS INPUT

Figure 31. Synchroscope.

general-purpose oscilloscope. The potentiometer used as a synchronizing amplifier with its own controls to provide triggered sweeps. Retrace blanking, marker generators, and voltage calibrators, which are not ordinarily found in the general-purpose oscilloscope, are also included in the circuitry of the synchroscope; these features will be covered under special circuits.

12-2. **Cathode-Ray Tube.** As you know, the heart of an oscilloscope is the *cathode-ray* tube. This is a special type of electron tube (see fig. 32) in which electrons emitted by a cathode are focused and accelerated to form a narrow beam having high velocity. The beam is controlled and directed so that it strikes a flourescent screen, whereupon light is emitted at the point of impact to produce a visual indication of the beam position. The electronic process of forming, focusing, accelerating, controlling, and deflecting the electron beam is accomplished by the electron gun in conjunction with the vertical and horizontal deflecting plates. A flourescent screen visually indicates the movement imparted to the electron beam. An aquadag (graphite) coating, which partially covers the inside of the glass envelope, provides a return path for electrons and at the same time serves to shield the electron beam electrostatically from external electrical disturbances.

12-3. *Electron gun.* A simplified form of the electron gun is shown in figure 32. The cathode

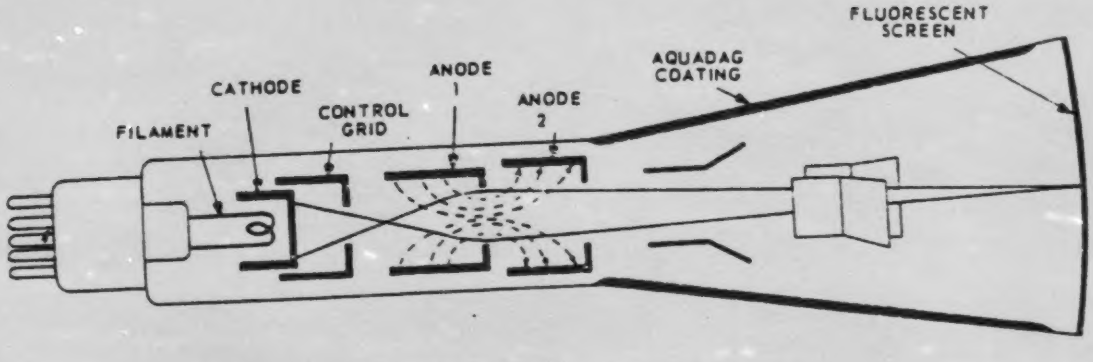

FLUORESCENT SCREEN
AQUADAG COATING
ANODE 1
ANODE 2
CATHODE
CONTROL GRID
FILAMENT

Figure 32. Electrostatic cathode-ray tube.

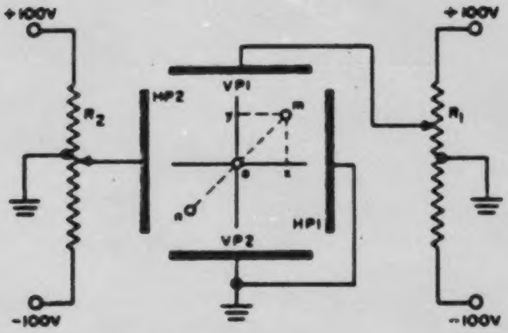


Figure 33. Electron beam deflection

is an oxide-coated metal cylinder which, when properly heated, emits electrons. These electrons are attracted toward the accelerating and focusing anodes, which are highly positive with respect to the cathode. To reach these anodes, the electrons are forced to pass through a tiny circular opening in a cylindrical control grid. The control grid effectively concentrates the electrons and starts the formation of a beam. Electrons leaving the grid aperture continue to travel toward the focusing anode (anode No. 1) and accelerating anode (anode No. 2). Note that the anodes are also cylindrical in shape and have openings to permit beam passage. Between these two anodes is an electrostatic field, shown by the dashed lines in figure 32, which causes the electrons to converge into a more concentrated beam. Thus, this electrostatic field serves as an electron lens which focuses the electrons in somewhat the same manner that a convex lens focuses a beam of light. The focal length of the electron lens is changed by varying the potential on anode No. 1 by means of a potentiometer located on the front panel of the oscilloscope. The potential on the second, or accelerating, anode remains constant. The intensity of the beam (number of electrons in the beam) is varied by varying the grid potential with respect to the cathode, thus permitting more or fewer electrons to flow. Because the potentials applied to the grid and both anodes are taken from a common voltage divider network, any change made in the setting of the intensity control requires an adjustment in the setting of the focus control, and vice versa.

12-4. *Electrostatic deflection.* Electrostatic beam deflection is accomplished through the use of two pairs of parallel plates located on each side above and below the beam. Two plates are horizontally oriented so that they are perpendicular to the two vertical plates; thus, the electrons must pass between the plates of each set of deflection anodes (see fig. 33). If no electric field exists between the plates of either pair, the beam follows its normal straight-line path, and the resulting spot is at or near the center of the screen. A voltage potential applied to one set of plates causes the beam to bend toward the plate that has the positive potential, and away from the plate that has the negative potential. Deflection of the beam occurs virtually instantaneously since it possesses an infinitesimal mass, and the bending is in direct proportion to the amplitude of the voltage applied to the plates. The second pair of plates influences the beam in the same manner except that the bending occurs in a plane perpendicular to the first. The plates located nearest the gun structure are generally designated as the *y*-axis deflection plates, and those nearest the screen as the *x*-axis plates. A voltage that is variable and recurrent with time, when applied to either set of plates, causes the spot to move back and forth across the screen along a straight line. The movement of the spot across the screen appears as a solid line when its cyclic rate exceeds the persistence of human vision or the persistence of the phosphor material forming the screen.

12-5. Nearly all applications of electrostatic-type cathode-ray tube require that each pair of deflection plates act on the beam independently and simultaneously. This produces a motion of the spot along a line which is the resultant of the forces exerted by the deflection plates. In this case, the electron beam is continually acted upon by two forces which are at right angles to each other. Figure 33 illustrates the resultant spot motion produced by independent deflection voltages applied simultaneously to the *x* and *y* axes. When the sliders of potentiometers R1 and R2 are at ground potential, all four deflection plates are at ground potential and the spot appears at 0 on the screen. If the slider of R2 is moved in a negative direction, horizontal deflection plate HP2 becomes negative with respect to HP1, and the electron beam is repelled by this negative voltage. Under the action of this repulsion, the spot moves to point *x* on the screen. If the slider of R1 is moved in the positive direction, vertical deflection plate VP1 becomes positive with respect to VP2, causing the beam to be attracted from point *x* to point *m*. Now, if the above adjustments of R1 and R2 are made simultaneously and at the same rate, the resultant of the electrostatic forces exerted along the *x* and *y* axes causes the spot to move to point *m* along the line *om*. If the same control setup is turned in the other direction, the spot moves along the line *on*. Thus, it is demonstrated that when two voltages, whether

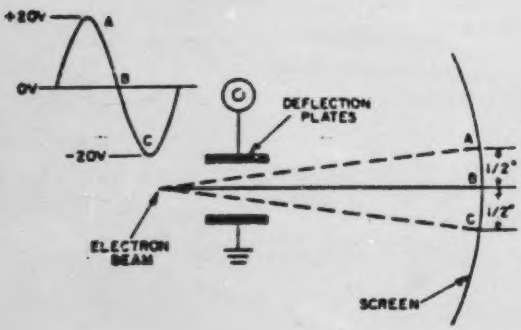


Figure 34. Deflection sensitivity.

they be steady voltages or variable in nature, are applied simultaneously, one to each pair of deflection plates, the position of the spot at any instant is proportional to the resultant of the simultaneous forces exerted upon the beam at that instant.

12-6. Deflection sensitivity. The distance that the spot may be moved upon the viewing screen in either the horizontal or the vertical direction by a potential of 1 volt applied to the deflection plates is the deflection sensitivity for the axis under consideration. This is usually given in millimeters per DC volt by the manufacturer, as one of the cathode-ray tube's characteristics. The most accurate way of measuring deflection sensitivity is to apply a known DC potential directly to the deflection plates and then to measure the distance the spot moves. This distance, in millimeters, divided by the voltage applied, is the deflection sensitivity for that pair of deflection plates (expressed in mm/volt). Most cathode-ray tubes have sensitivities of less than 1 mm/volt.

12-7. Another way of expressing the ability of an applied voltage to cause beam deflection is called the *deflection factor.* Deflection factor is the voltage required on a pair of deflection plates to produce unit deflection of the spot, and is usually expressed at DC (or RMS) volts per inch. If a tube has a deflection factor of 60 VDC per inch, the spot moves a total distance on the screen of 1 inch for every 60 volts applied to the deflection plates; hence, 120 VDC would displace the spot 2 inches.

12-8. If an AC voltage is applied to one pair of the deflection plates, the spot is never stationary on the screen of the scope because the deflection of the beam is at all times proportional to the instantaneous voltage on the deflection plates. As a result, the electron beam scans the screen in such a manner as to produce a straight, luminous line, the length of which is determined by the peak-to-peak value of the voltage. It can be seen from figure 34 that, when an AC voltage is applied to the vertical deflection plates, the electron beam is deflected upward and downward from its rest position by equal amounts. Assume that the vertical deflection system shown in figure 34 has a deflection factor of 40 VDC per inch and that the sine-wave voltage applied to the plates has a peak-to-peak value of 40 volts. Under these conditions, the upward and downward deflections from the center are each 1/2 inch, producing a vertical line 1 inch long. The spot retraces this path at the frequency of the applied signal.

12-9. The *x* and *y* deflection sensitivities for cathode-ray tubes employing electrostatic systems are not equal—the vertical, or *y*, plates generally have the greater sensitivity. The inequality results from the differences in their positions with repsect to the viewing screen, because it is not a practical design to mount both sets of plates at a common distance from the screen. The most desirable characteristics for a particular application should be chosen. For example, if the ultimate in deflection sensitivity is essential, then (1) the tube must be long, (2) the second anode potential must be kept low, and (3) the effective spacing of the deflection plates must be small. If the tube must be short or if the anode voltage must be kept high for purposes of best spot size and high brilliance, the sensitivity is reduced. A method often used for increasing deflection sensitivity is to increase the time during which the deflection potentials may act upon the beam and to decrease the spacing between plates. This can be done effectively by installing long, closely spaced plates that bend away from the deflection path to permit a wide angle of deflection without interception of the beam by the plates.

12-10. *Fluorescent screen.* In order to convert the energy of the electron beam into visible light, that area where the beam strikes (labeled *screen* in fig. 34) is coated with a phosphor chemical which, when bombarded by electrons, has the property of emitting light. This property is known as *fluorescence.* The intensity of the spot on the screen depends upon two factors—the speed of the electrons in the beam and the number of electrons that strike the screen at a given point per unit of time. The amount of light per unit area which the phosphor is capable of emitting is limited and, once the maximum has been reached, any further increase in the electron bombardment has no further effect on the intensity of the light. In practical cases, the intensity is controlled by varying the number of electrons that are allowed to reach the screen. All fluorescent materials have some afterglow, which varies with the screen material and with the amount of energy expended to cause the emission of light.

12-11. The length of time required for the light output to diminish by a given amount after excitation has ceased is the *persistence* of the screen coating. The general classification of screen materials is in terms of *long, medium*, or *short* persistence. Various phosphors are used in oscilloscope work, each for specific applications. For example, white and blue-white phosphors of short and very short persistence are used where photographic records are taken of screen patterns. Again, for general service work, where visual observation is most important, a green phosphor having medium persistence is used. In viewing a line or pattern that is traced by a moving spot of light, the persistence of human vision, as well as that of the screen material, plays an important part. When the pattern is retraced at a rate of 16 times or more a second, the persistence of the eye retains the image from each previous sweep; therefore, the spot in its movement is no longer distinguishable as a spot, and the path traveled appears as a continuous illuminated line. In the case of long-persistence phosphor materials, the persistence of the screen rather than the eye is the governing factor, and the scanning rate required to produce a solid line is substantially lower.

12-12. *Aquadag coating.* As we have previously described, the fluorescent screen of a cathode-ray tube is bombarded by a beam of electrons. If these electrons were allowed to accumulate upon the screen, the screen would soon acquire a negative charge that would effectively repel and disperse the electron beam, thus blocking the tube in its primary function. However, this does not occur because the beam, upon striking the screen, dislodges electrons from its surface (a process known as *secondary emission*). These dislodged electrons are attracted to positively charged tube elements, whereupon they are returned to the power supply. When the number of secondary electrons conducted away from the screen equals the number of electrons that return to the screen plus those that are delivered to the screen, there is no accumulation of charge. Present-day cathode-ray tubes have a coating of graphite painted upon the inner surfaces but not connected with the screen. The functions of this coating are (1) to collect and return secondary electrons to the power supply, (2) to serve as an electrostatic shield against external electrical fields, and (3) in some tube types, to act as an accelerating anode.

12-13. **Basic Circuits.** Oscilloscopes and synchroscopes require power supplies, amplifiers, and sweep generator circuits.

12-14. *Power supplies.* High-voltage and low-voltage power supplies are required for the operation of scopes. The high-voltage power supply provides operating potentials to the cathode-ray tubes. The low-voltage power supply provides operating potentials to the associated amplifiers and oscillators.

12-15. The output of the high-voltage power supply is usually over 1000 VDC, depending upon the size of the cathode-ray tube. Its polarity is negative to permit the second anode and the deflection plates to be operated at ground potential; this also provides an additional safety factor. Half-wave rectification and a simple resistance-capacitance filter network are used for these high-voltage applications because the current required to operate the cathode-ray tube is very small. A voltage divider, which includes the focus and intensity controls, provides the necessary operating potentials for the various cathode-ray tube electrodes.

12-16. The output of the low-voltage power supply is usually in the 250- to 400-volt range. Full-wave rectification and a pi-type filter network are used in this power supply because of the moderate current, good regulation, and low ripple voltage requirements.

12-17. Both the low-voltage and high-voltage power supplies use a common secondary on the power transformer. This design, in conjunction with the use of half-wave rectification for the high-voltage supply, permits a saving in copper as well as space, because the low-voltage secondary provides a portion of the high-voltage output.

12-18. *Vertical and horizontal amplifiers.* The deflection system of the cathode-ray tube is relatively insensitive, requiring voltages on the order of several hundred volts for full-scale deflection. Therefore, it is necessary to use amplifiers to increase the amplitudes of the voltages for both the vertical and horizontal deflection plates so that test signals of low amplitudes may be effectively presented.

12-19. Most oscilloscopes use a cathode follower input stage followed by push-pull amplifiers to obtain better linearity at the output of the horizontal and vertical deflection channels. One of the most important advantages of using push-pull amplifiers, instead of single-ended amplifiers, is that the deflection plates produce a uniformly balanced field with respect to the second anode of the cathode-ray tube. This eliminates the tendency for the spot to

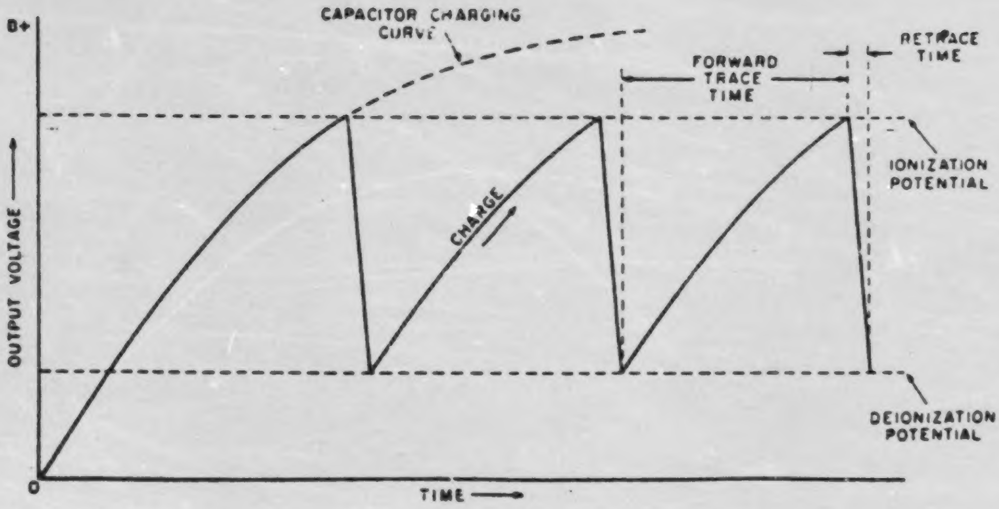


Figure 35. Thyratron sweep waveform.

defocus as the electron beam approaches the limits of the viewing area. From a given power supply, a push-pull amplifier can deliver twice the output signal that a single-ended stage can deliver. Moreover, push-pull operation tends to reduce the generation of internal noise. The use of a cathode follower as an output circuit provides the advantages of a higher input impedance and less frequency discrimination.

12-20. In synchroscopes and some general-purpose oscilloscopes, the design of the amplifiers provides complex frequency-compensating networks and direct coupling in plate, grid, and/or cathode circuits, to extend the high- and low-frequency response. Wide frequency response, however, is obtained at the expense of signal gain. Thus, to broaden the response, the number of amplification stages must be increased if the same deflection sensitivity is desired.

12-21. When an amplifier is used between the signal source and the deflection plates of the cathode-ray tube, the signal is faithfully reproduced only when the amplifier overloading point and frequency range are not exceeded. The overloading point is reached when the amplitude of the signal under observation exceeds the dynamic operating capabilities of the input amplifier. Oscilloscopes using a simple potentiometer as an input gain control are especially susceptible to *overloading* conditions. High input signal levels can produce deflection voltages so large that the display dimensions exceed the viewing area dimensions; signal extremities are not visible. Such a display is not usable in this condition; therefore, the gain control must be decreased until the point is reached where the control is so near the end of its rotation that adequate control of the display dimensions is difficult to obtain. Two other difficulties encountered with the use of a single gain control are *frequency discrimination* and *phase distortion*. As the higher input frequencies are varied, they are adversely affected by the gain control because of the shunting effects of the distributed capacitance of the high-resistance potentiometer rotor to ground. The problem is complicated by the fact that the shunting effect is increased or decreased for the same frequency with a change in the resistance setting. Phase distortion is also a function of this control for the same reason.

12-22. Many oscilloscopes include a step-type, frequency-compensated attenuator switch preceding the first vertical amplifier and gain control to reduce the effects of overloading, frequency discrimination, and phase distortion. This switch often provides a direct-current position, connecting the grid of the first vertical amplifier so that circuits producing a direct-current restoration may be observed and measured. Attenuators of this type are seldom encountered in the horizontal amplifier, because routine maintenance procedures generally require the use of the internal time-base generator and also because the sensitivity of the horizontal amplifier is lower due to the location of the horizontal deflection plates within the cathode-ray tube.

12-23. *Sweep generators.* The sweep generator circuits in many general-purpose oscilloscopes employ a *thyratron* to generate a sawtooth sweep. The sweep generator provides

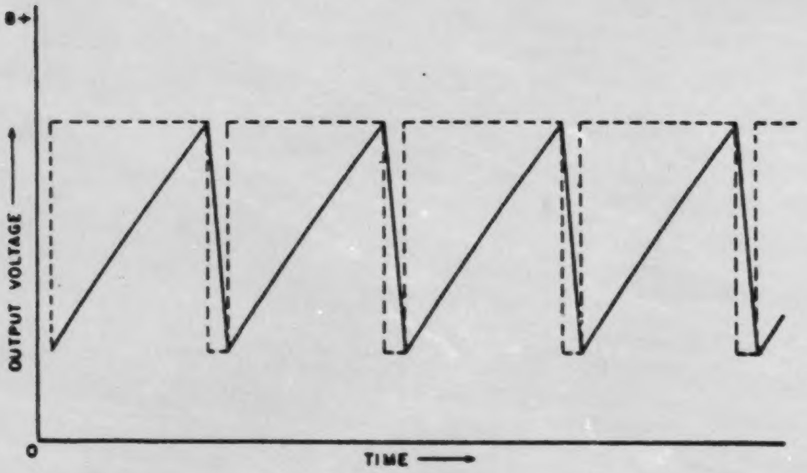


Figure 36. Multivibrator sweep.

a wide range of fundmental sawtooth frequencies with a reasonably linear forward trace and a rapid retrace time for general-purpose time-base applications (see fig. 35). The advantage of a thyratron sweep circuit over the simpler gaseous discharge circuits is more stable synchronization of the sawtooth sweep with other waveforms in various harmonic, subharmonic, and phase relationships to produce a stationary display.

12-24. The operation of the thyratron sweep generator is based upon the fundamental principle of charging a capacitor through a resistance from a constant potential source (see fig. 35). The frequency of the sweep generator is primarily determined by the time constant of the charge time capacitor and resistor, but the exact frequency is also affected by the ionization and deionization levels of the thyratron. In general, increasing the resistance-capacitance (RC) time constant decreases the sawtooth frequency, while decreasing this time constant increases the frequency. At the lower frequency sweeps, the desired control over the generator frequency is more positive acting and more easily obtained by the use of a high-resistance potentiometer to increase the RC time constant.

12-25. The forward trace time of the sweep occurs when the amount of charge accumulated within the timing capacitor increases with equal increments of time. The forward trace, then, is produced by the charge time of the resistor-capacitor combination. Near the end of the forward trace time, the amplitude of the charging wave becomes equal to the ionization level of the thyratron sweep tube. At this time in the cycle, the gas-filled tube conducts to discharge the time charging capacitor. When the RC combination has been discharged to the point where the deionization potential of the thyratron is reached, the thyratron ceases to conduct. This portion of the sawtooth wave is called the *flyback*, or *retrace*, time. The sawtooth waveform is completed at this point, and the circuit continuously repeats the entire cycle of events. There are three generally used terms to describe the sweep with this mode of sweep generator operation: *continuous*, *free-running*, and *recurrent*.

12-26. Vacuum tubes and transistors are also commonly used to produce sawtooth sweep signals for driving the horizontal deflection amplifiers. Multivibrators of various types, as well as blocking oscillators, are used to generate these signals. Multivibrators used for the generation of sawtooth signals are asymmetrical; that is, two pulses are produced per operating cycle, but they are of unequal time duration. The longest pulse is used to derive the forward trace time, while the shortest pulse is used to derive the retrace time, as shown by the dotted lines in figure 36. A comparatively large capacitor is placed across the output terminals of the multivibrator to convert the rectangular pulses into a sawtooth sweep signal. Blocking oscillators are usable as sweep generators, but general-purpose oscilloscopes used by the Air Force seldom have blocking oscillator sweep circuits.

12-27. Sawtooth sweep signals derived from constant voltage sources, such as those just described, do not produce a sweep of sufficient linearity for some applications. The reason is that the charging voltage follows an exponential curve instead of the desired

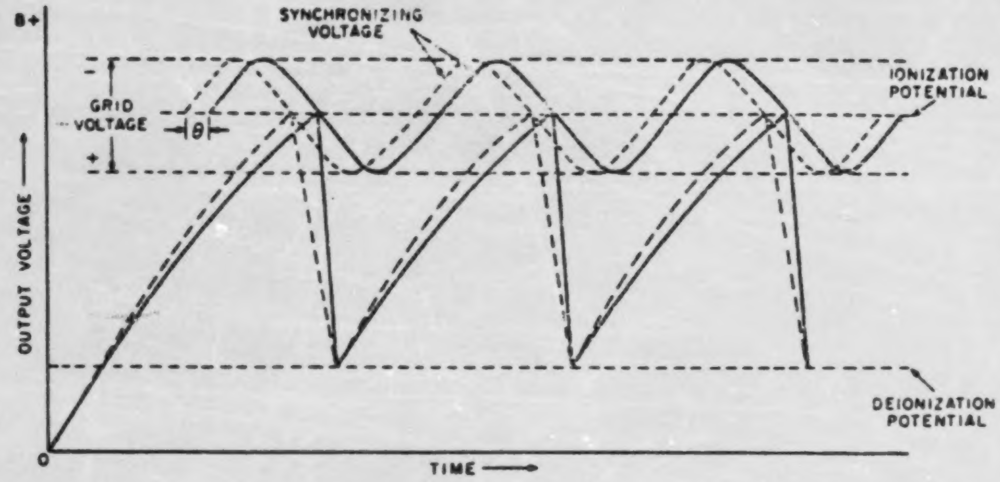


Figure 37. Synchronizing the sweep.

straight line. By replacing the resistor in an RC time-determining network with a pentode vacuum tube, a more linear sweep can be obtained. The high plate resistance of the pentode, together with its constant current properties, makes it well suited for this purpose.

12-28. In addition to linearity, synchronization is important. While it is true that a stationary display can be obtained by adjusting the sweep generator to some harmonic or subharmonic relationship with the unknown signal in the vertical amplifier, it does not mean that the display remains stationary indefinitely. Fluctuations in either the sweep or test signal, or both, cause the two signals to lose this synchronism. If the sweep is not precisely in step with the voltage under test, the resulting display is a moving display, and unless the movement is very slow, the display is unintelligible to the observer. Many times, it is extremely difficult to obtain a stationary display despite the harmonic relationship of the test and sweep signals.

12-29. Although more stable synchronous operations, can be obtained with vacuum-tube and solid-state sweep circuits than with a thyratron sweep circuit, many oscilloscopes employ the thyratron because it permits simpler design and is satisfactory for ordinary applications. A method of locking the sweep generator to the frequency of the test signal is to inject a portion of the test signal being processed in the vertical amplifier into the grid of the thyratron. For example, if no synchronizing voltage is applied to the grid of the thyratron, the sweep generator becomes uncontrolled and operates in a free-running condition; i.e., its frequency is governed solely by the RC time constant of the circuit, shown by the solid line sawtooth signal in figure 35. Reference to figure 37 shows that even though the solid line synchronizing sine wave does not materially affect the free-running sweep frequency, synchronism is obtained. If the sweep signal tended to change along the time axis, the sine wave would trigger the thyratron to terminate the forward trace time. Figure 37 also shows how the horizontal sweep is brought into synchronism if the same sine-wave frequency is advanced in phase by $\theta°$. Note the dotted line sine-wave and sawtooth sweep portions.

12-30. **Special Circuits.** As we have mentioned earlier, scopes may have special circuits to make them more accurate and versatile.

12-31. *Triggered sweep.* The sawtooth sweep generator in the general-purpose oscilloscopes is usually of the free-running type. Although a synchronizing signal injected into the sweep generator can control and initiate the sweep, the free-running frequency of the sawtooth sweep must closely match or be some multiple of the synchronizing signal to provide lock-in operation. Consequently, when the synchronizing signal consists of random pulses, or pulses having low repetition rate, satisfactory displays cannot be obtained. Consider the case where a pulse of 1/2 μsec in width is to be observed at a repetition rate of 1000 pulses per second (PPS). The sawtooth sweep would have to be about 1 μsec long to display the pulse; however, for each pulse observed there are 999 idle sweep periods of the time base generator. Loss of

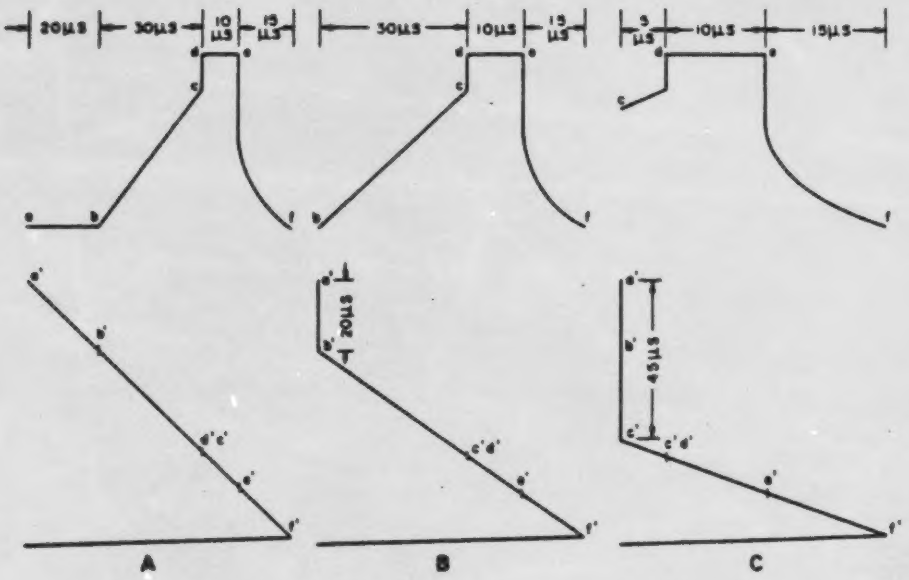


Figure 38. Triggered sweep and displays.

synchronization during the 999 idle periods could produce an erratic display, because the pulse could be located in a different position for each successive sweep. Furthermore, in most cases, the observed pulse is small and faint as compared with the long, bright baseline representing the idle periods.

12-32. To overcome this difficulty, the *synchroscope* was developed. It has a triggered or driven sweep which is time controlled. During quiescent signal conditions, the capacitor in the time-determining network is held in a discharged state. The spot remains at the left-hand side of the scope viewing area during this time. When a synchronizing pulse of the proper amplitude and polarity is derived from the signal under investigation, the sweep-forming capacitor is permitted to charge, commencing a single sweep. Following the attenuator of the vertical amplifier is an artificial delay line or a low-pass filter circuit with a cutoff frequency higher than the highest frequency to be passed. One purpose of this delay circuitry is to retard the signal to be observed until the sweep has been initiated by a portion of the input signal, which is not delayed. If the delay were not used, the initial portion of the waveform would not appear on the trace, because a certain amount of time is required for the input signal voltage to rise to the level needed to trigger the sweep circuit.

12-33. The delay period may be fixed or variable. If the delay is variable, the triggered sweep may be initiated to lead or lag the signal source by some predetermined amount to permit investigations of any portion of a particular waveform. Figure 38,A, shows the undistorted waveform displayed by a single sweep from the internal time-base generator. In figure 38,B, the sweep frequency and delay were changed so that the sweep would be initiated 20 μsec after the start of the waveform to be displayed. The undesired detail of the line segment represented by line *ab* is eliminated by the delay circuit, and the entire step pulse is expanded along the horizontal direction. Changing the sweep frequency and delaying the sweep for 45 μsec, as shown in figure 38,C, permits an even greater expansion of the step pulse for the examination of any detail along the peak of the pulse.

12-34. A secondary purpose of the delay line is to provide a means of reflection, a series of accurately spaced pulses suitable for calibration of short time intervals. To accomplish this, a switch is provided to cause a mismatch in the termination of the delay line so that when a sharp pulse is fed into the line, a series of reflections will occur similar to those shown in figure 39. Since the time required for a pulse to travel down the line and back is 1 μsec, a series of pulses occurring 1 μsec apart is produced. Of course, each successive pulse is smaller because of losses in the delay line, but a significant number is available for most high-speed calibration purposes.

12-35. *Sweep calibrator.* The length of the sweep signal used for general waveform

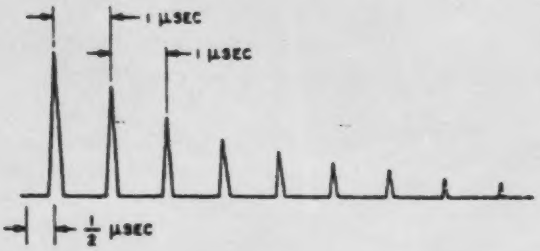


Figure 39. Marker pulses from a mismatched delay line

inspection need not be calibrated. The sweep controls are manipulated until a certain reference waveform specified by the maintenance routine is obtained. In many maintenance applications, however, calibration of the time axis is necessary. Such calibration is made with a sweep calibrator which supplies a highly stable output of known frequency. Consider the case where the output from the sweep calibrator provides a sine-wave signal of 1 megahertz per second (MHz) which is injected into the vertical deflection amplifier. The horizontal amplifier and sweep controls are then adjusted to produce a single sine-wave cycle display 1 inch wide. Since 1 MHz corresponds to a cyclic period of 1 µsec, the horizontal sweep is not calibrated for 1 µsec/inch. If the sweep calibrator supplies a frequency of 10 kHz, a cyclic period of 100 µsec is obtained. A trace made to be 1 inch long, therefore, has a horizontal sweep calibrated at 100 µsec/inch. Expanding the display to 4 inches results in a calibration of 25 µsec/inch.

12-36. Retrace time is also included in this type of time axis calibration, and thus produces a small error. The retrace time generally occupies only a small percent of the total sweep time; therefore, this calibration error can usually be neglected. In those applications where such an error cannot be tolerated, a marker generator must be used.

12-37. *Marker generator.* Sweep-time calibration is made with the aid of marker pulses produced by accurately adjusted tuned circuits. Marker pulses are often produced by the "ringing" of a succession of tuned circuits by the sweep oscillator itself, or by a separate oscillator of the multivibrator type, which produces a continuous series of harmonics spaced at convenient intervals.

12-38. Some types of internal marker generators are connected by suitable amplifiers to the grid of the cathode-ray tube and are also controlled by the sweep generator so that both the sweep and the markers are initiated at zero sweep time. In this way the sweep is divided into equal increments. The display trace is intensified during that period of the marker signal which makes the grid-to-cathode potential less negative. The displayed signal from the vertical amplifier is then "chopped up" into a series of bright segments of known length in terms of time. Typical marker intervals are switch selected to give 0.2-, 1-, 10-, 100-, and 500-µsec markers.

12-39. Another method, using the vertical deflection amplifier, mixes a succession of fixed markers with the signal under investigation. Figure 40,A, shows a signal undergoing inspection that does not have markers; thus, there is no way of gauging whether the pulses are of the correct width or whether the spacing between the pulses is accurate. By injecting marker pulses into the vertical amplifier, spaced at accurately known intervals (see fig. 40,B), we can now determine whether or not the pulses are arriving at the precise time desired and whether or not they are of the correct width.

12-40. Other types of markers, such as signal or absorption markers, are also used. These types of markers are generally obtained from auxiliary equipment and are injected or mixed with the signal under observation at the vertical input terminals of the oscilloscope or synchroscope.

12-41. *Voltage calibrator.* In many test and alignment procedures, a signal of known amplitude and waveform is required at the input of an amplifier, so that the resultant output of the amplifier may be observed, measured, and analyzed.

12-42. The amplitude of the waveform displayed may be measured by using a device known as a *voltage calibrator.* Voltage calibrators may be manufactured as auxiliary equipment, or they may be featured as part of the internal circuitry.

12-43. The fixed reference type of voltage calibrator clips the peaks of the 60-hertz AC filament source to closely approximate the shape of a square wave. The clipping diodes act also as clamps to produce a fixed peak-to-peak signal of 3 volts at an output terminal. Injection of this 3-volt peak-to-peak signal into the vertical amplifier permits you to manipulate the controls to obtain a display deflected to some convenient number of divisions on the scope calibration grid. The calibrating signal is then removed and, without changing any control settings, the unknown signal is substituted to give a new display. The number of divisions of the calibration grid are counted and the peak-to-peak signal is calculated; the calculation is

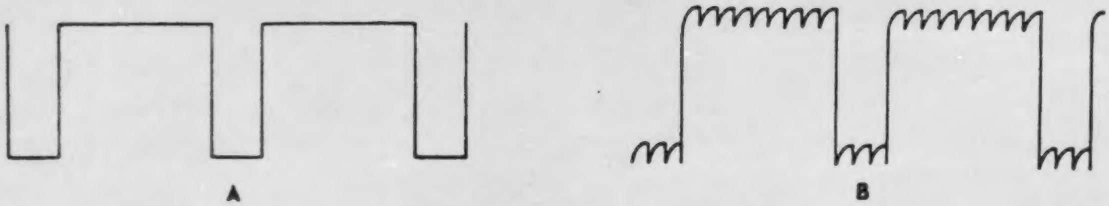


Figure 40. Marker injection.

based upon proportionate deflection with respect to the original display.

12-44. Other voltage calibrators provide a variable calibrated control, permitting you to measure the amplitude of displayed signals by comparing the unknown voltage with a variable amplitude pulse of known value. The displayed amplitude of the calibrating signal is adjusted to equal the amplitude of the displayed signal under investigation. The reading of the calibrated control may then be used directly or it may be calculated, as required.

12-45. *Retrace blanking.* The sawtooth waveform generated by the sweep generator has been discussed in detail with respect to the trace time, but little has been said about the retrace, or flyback, time.

12-46. *Retrace time* is the time required to switch the electron beam from the right-hand side of the viewing area to the left-hand side prior to initiating a new sweep. The time required to switch the beam varies with circuit constants, ranging from a few percent of the total sawtooth sweep time in special-purpose oscilloscopes to as much as 15 percent in general-purpose oscilloscopes. The intensity of the retrace depends upon the fundamental sawtooth repetition rate. If the fundamental repetition rate is low, the retrace is still clearly visible, even though the retrace, as compared with the forward trace, is extremely rapid.

12-47. Displays of low-frequency waveforms are least affected by retrace time, since the percentage of the waveform lost during the trace is small. The effect of this portion of the sawtooth sweep becomes progressively more noticeable until at some higher frequency a full cycle is displayed during retrace.

12-48. Rectangular waveform displays at high repetition rates can become confusing because of the retrace portion of the display (see fig. 41). A segment of a recurring cycle is displayed, consisting of a series of rectangular pulses that are periodically blanked in accordance with some circuit operating cycle. The display is confusing because it does not show the waveform expected.

12-49. To overcome this difficulty, a pulse of the proper amplitude and polarity is used to drive the grid of the cathode-ray tube to cutoff during retrace time. Thus, retrace blanking is actually an interruption of the electron beam during the time when the beam is being switched from the right-hand side to the left-hand side of the viewing area prior to the next sweep. When the sawtooth sweep is initiated once again, the grid of the cathode-ray tube is unblanked, permitting the electron beam to excite the screen phosphor.

12-50. Figure 42 shows the same signal as previously shown in figure 41, but with retrace blanking taking place. Notice that the retrace time used throughout the discussion shows that retrace time can prevent the display of a considerable portion of the total signal under observation. This is true whenever the repetition frequency is high enough. As we have previously explained, the loss of the pulse is due to a relatively long retrace time and cannot be altered by retrace blanking.

12-51. *Expanded sweep.* Circuitry to permit the expansion of selected segments of the display in the horizontal direction are featured in many types of oscilloscopes and synchroscopes. By the use of such equipment, the leading and trailing edges of expanded pulses—especially in radar maintenance routines—can be explained in much greater detail. A positioning potentiometer is used to control a delay trigger circuit so that the expanded sweep commences at any selected point with respect to the normal forward trace of the sawtooth sweep. Additional amplification of the sweep from the trigger point produces a sawtooth waveform that is deliberately distorted by a known factor. This added amplification is fixed to some value such as 3X, 5X, or 10X, or a switch may be provided to select the expansion factor desired. The switch is calibrated as a multiplier so that the sweep rate through the expanded portion of the display may be calculated. Provision is made in some of these instruments for adjusting the expansion notch to a width that is 15 to 25 percent of the total sweep length anywhere along the length of the normal sawtooth length.

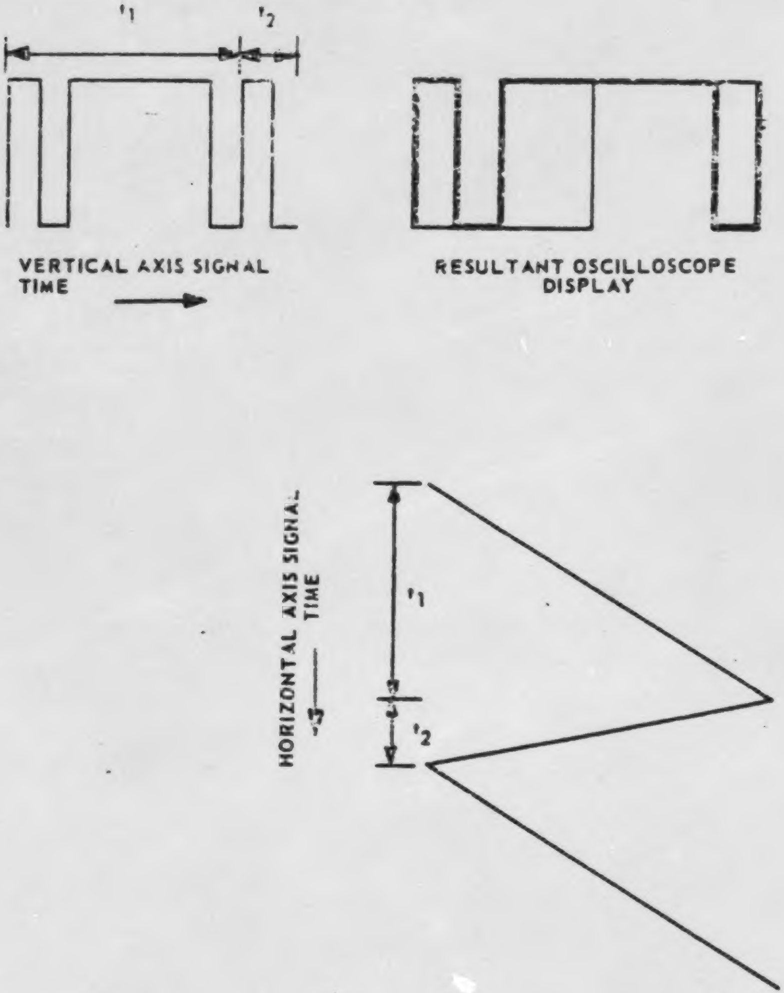


Figure 41. Effect of retrace.

13. Oscilloscope Controls and Operating Considerations

13-1. You are well aware of the fact that the measurement and comparison of waveforms is a very important part of the circuit analysis used in troubleshooting. In some circuits (for example, pulse circuits), waveform analysis is indispensable. Waveforms may be observed at test points shown in waveform charts or schematic diagrams that are a part of Air Force technical manuals supplied for each equipment. You should realize, however, that the waveforms given in instruction books are often idealized and do not show some of the details that are normally present when the actual waveform is displayed on an oscilloscope or synchroscope. Nevertheless, by comparing the observed waveform with the reference waveform, faults can be localized rapidly.

13-2. If there is no trouble present in the equipment, a waveform observed at a point in the equipment should closely resemble the reference waveform given for that test point. The reference waveforms supplied in the technical manuals are the criteria of proper circuit performance. However, test equipment itself or the use of test equipment can cause distortion of the observed waveforms, even though the equipment is operating normally. We discuss several of the most common causes of these conditions in this section—and also remind you of some practical considerations and precautions of importance.

13-3. **Controls.** Most Air Force technical manuals clearly state when and where to connect an oscilloscope into a circuit to perform preventive or corrective maintenance procedures. These manuals also have

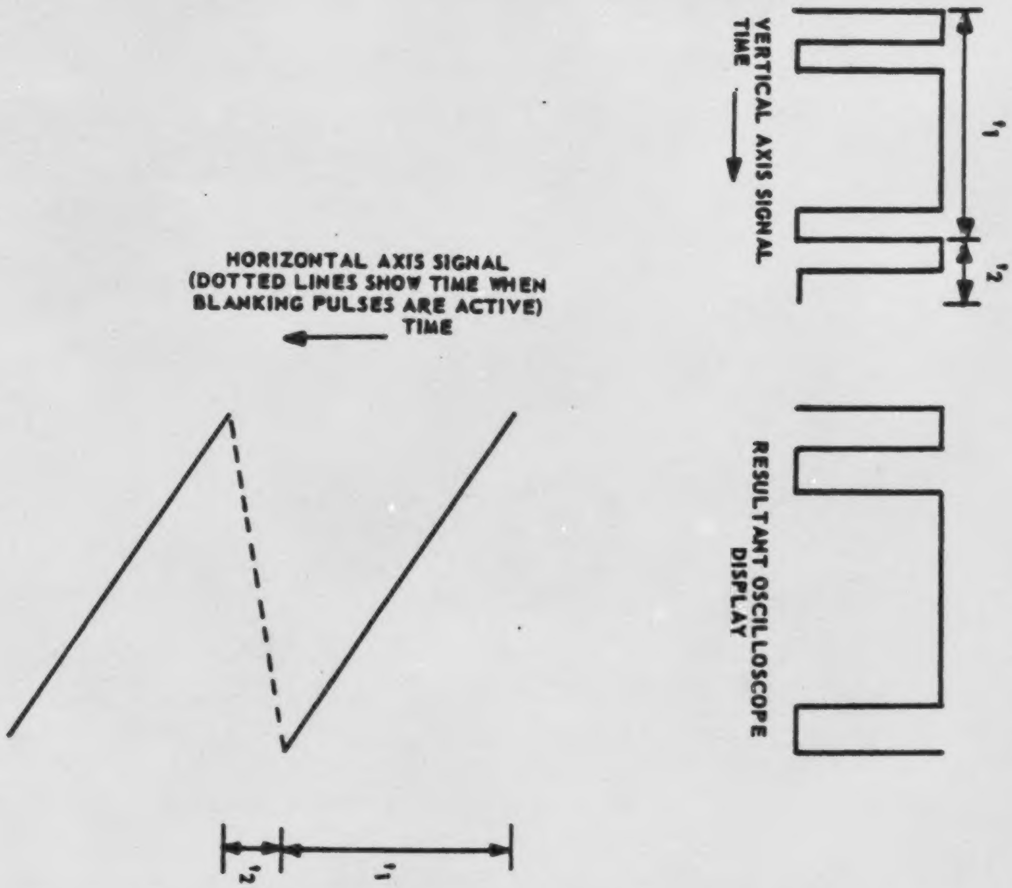

VERTICAL AXIS SIGNAL
TIME
t_1
t_2
HORIZONTAL AXIS SIGNAL (DOTTED LINES SHOW TIME WHEN BLANKING PULSES ARE ACTIVE)
TIME
RESULTANT OSCILLOSCOPE DISPLAY
t_2
t_1

Figure 42. Effect of retrace blanking.

illustrations to show you the appearance of the desired waveform at selected points. The choice and manipulation of oscilloscope controls, except for special routines, is left to your discretion. NOTE: Unfortunately, displays often show waveforms at points not discussed by these manuals; in addition, the displays shown may be modified by adjustment of controls which are not mentioned in the text of the routine because you are expected to manipulate the controls without being instructed to do so.

13-4. *Focus and intensity.* The two basic controls affecting the readability of the scope display are the beam intensity and focusing controls. These two controls are considered together because they interact to such an extent that the adjustment of one usually requires the adjustment of the other.

13-5. The *intensity control* is used to adjust the spot to the brightness desired. When the spot has no motion, it becomes brighter, larger, and out of focus as the intensity control is rotated toward maximum intensity. Further rotation of this control produces secondary emission effects, causing a halo around the spot. When the halo appears, the intensity control must be decreased to eliminate the halo before the fluorescent screen is permanently damaged. The halo from an excessively bright spot disappears to some extent when the electron beam is subjected to the deflection fields, because the energy in the electron beam is distributed over a much greater area. The use of the spot in this condition produces a wide trace and tends to obliterate or mask any available fine detail.

13-6. The *focus control* is used to produce a round spot with a clearly defined edge. A stationary spot becomes smaller and charper when the focus control is rotated toward the maximum value. Further rotation of this control beyond the focal point again produces an out-of-focus spot.

13-7. A poorly focused spot can result in an elliptical instead of a round spot. When the

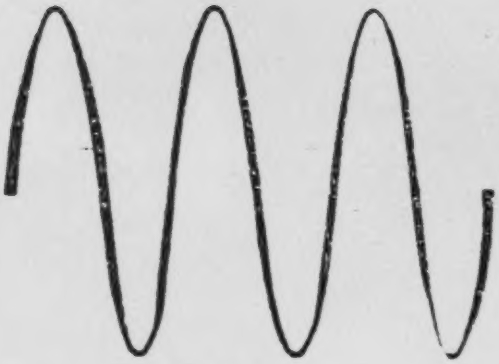


Figure 43. Poor focusing.

elliptical spot is set into motion under the influence of deflecting fields, it is noticeable as a line of variable thickness. For example, if the ellipse is lying horizontally, it produces a thin line only at the peaks of a sine wave, while the positive- and negative-going portions of the sine wave are considerably thickened, as shown in figure 43.

13-8. Depending upon the velocity of the spot, an increase in spot intensity may be required, because the rapidly moving spot does not remain in one position long enough to fully excite the phosphor screen of the cathode-ray tube. This effect may often be observed when you are viewing sqaure waves where the rise and decay times are extremely rapid (see fig. 44).

13-9. *Gain*. The basic controls that determine the size of the oscilloscope display are potentiometers used as the horizontal and vertical gain controls. The *horizontal gain control* permits the width of the display to be increased or decreased; similarly, the *vertical gain control* permits the height of the display to be increased or decreased.

13-10. An attenuator preceding the gain control is sometimes encountered and is usually associated with the vertical amplifier. The step attenuator, often referred to as a multiplier, is usually calibrated in steps of 1X, 3X, 10X, 30X, and 100X; the attenuation at each step is expressed with respect to the attenuation range at step 1X. Operation of this control results in abrupt changes in the oscilloscope display because of sharp changes in the input signal level. The attenuator is called a *multiplier* because the oscilloscope can be used as a direct reading, peak-to-peak voltmeter, once the vertical amplifier is calibrated. Calibration is accomplished by setting the attenuator to 1X, injecting a signal of known amplitude, follwed by a display adjustment to vertical dimensions of convenient known height. Advancing the gain control too far for a given signal or applying a signal that exceeds the amplification capabilities of the horizontal or vertical amplifiers results in overloading and, consequently, distortion.

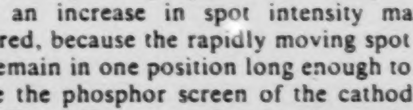
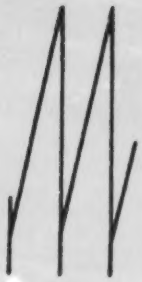


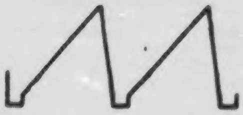
Figure 44. Effect of trace speed on beam intensity.

13-11. Interpretation of an observed waveform depends greatly upon proper proportioning of the horizontal and vertical dimensions of the oscilloscope display. Uncertainty or lack of knowledge concerning the signal that an amplifier is processing, together with improper display proportioning, can lead to an erroneous conclusion concerning the test circuit. Figure 45 shows the display of a trapezoidal waveform where the horizontal and vertical dimensions are acceptable. By contrast, if both the horizontal and vertical gain controls are changed in a random manner so that the change in the vertical direction predominates to produce the oscilloscope display shown in figure 45,A, the characteristics of the trapezoidal waveform shown in figure 45,B, become masked. If you had no previous knowledge that the waveform was supposed to be a trapezoid, you could reach the erroneous conclusion that the display was a sawtooth waveform. On the other hand, if you know that the circuit processes a trapezoidal wave and wish to closely inspect the waveform for any irregularities, such a proportioning of the display is entirely acceptable and advisable. Changing the horizontal and vertical gain controls once more to the opposite extreme so that the display is exaggerated predominantly in the horizontal direction produces a waveform like that shown in figure 45,C. Under these conditions, the trapezoidal waveform viewed on the oscilloscope screen could be interpreted as a sawtooth waveform with excessive retrace time.

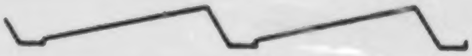
13-12. A height-to-width ratio of approximately 2:3 or 4:5 provides optimum display proportions for general-purpose waveform examinations. Once you are certain of the waveform you are inspecting, expansion (maintaining the same ratio) or exaggeration of the waveform in the vertical or horizontal



A
TRAPEZOIDAL WAVEFORM INCORRECTLY PROPORTIONED; VERTICAL GAIN HIGH, HORIZONTAL GAIN LOW



B
TRAPEZOIDAL WAVEFORM CORRECTLY PROPORTIONED



C
TRAPEZOIDAL WAVEFORM INCORRECTLY PROPORTIONED; VERTICAL GAIN LOW, HORIZONTAL GAIN HIGH

Figure 45 Vertical-to-horizontal proportioning.

direction to observe waveform irregularities may be very advantageous.

13-13. Sometimes the signal at the point under examination is so small that a display of more than 1/2 inch in the vertical dimension cannot be obtained. The horizontal dimension of the display must also be reduced so that the display is correctly proportioned. A reduction in beam intensity, followed by a refocusing of the spot, generally produces a display that is easier to view.

13-14. *Positioning*. The vertical and horizontal positioning controls permit you to shift the position of the entire desplay to any portion of the viewing area desired. The *vertical positioning control* is a continuously variable potentiometer that permits the display to be moved up or down by any amount, including those positions away from the viewing area. Similarly, the *horizontal positioning control* permits the side-to-side movement of the entire display.

13-15. Occasionally, during an examination of a waveform, irregularities may be noticed at or near some extremity of the display. The display may be enlarged by means of other scope controls and then positioned by the horizontal and vertical positioning controls so that the irregularity under inspection appears within the center of the viewing area. The remainder of the signal, of which the irregularity is only a small part, is then deflected off the screen toward the neck of the cathode-ray tube where these portions of the signal cannot be viewed. At the edges of the tube, the display being deflected off the screen widens and becomes considerably blurred at the rim of the tube. This distortion is due to the curvature and reinforcing thickness of the glass at this point of the tube envelope.

13-16. When expanding a display for the purpose of close signal inspection, you may also expect some distortion at or near the maximum control positions. Such distortion should not be attributed to the cathode-ray tube, because it is due to nonlinearity characteristics of the horizontal and vertical amplifiers.

13-17. The horizontal and vertical positioning controls also serve a secondary purpose. Since the structural imperfections in the manufacture of cathode-ray tubes may cause the beam to strike at some point other than the center of the screen when no deflecting signals are applied, it is necessary to provide some means of positioning the beam. This is usually done by applying small DC potentials to the deflection plates by means of potentiometers similar to those described earlier and illustrated in figure 33.

13-18. *Polarity reversal*. Comparison between the reference waveform and the display obtained from operating equipment can best be made if it is known which direction the spot moves when a positive voltage is applied. Normally, oscilloscopes provide an upward spot deflection with a positive input signal. However, some oscilloscopes provide a switching arrangement in the vertical amplifier, whereby the beam can be switched to provide either an upward or a downward deflection with a positive input signal. This switch may be located in the grid section of the vertical input amplifier or at the grid or grids of the vertical output amplifier.

13-19. *Frequency*. The coarse and fine frequency controls of an oscilloscope permit you to change the frequency of the sawtooth sweep generator. The *course frequency control* is a multiposition rotary switch that permits you to select the desired range of sawtooth frequencies by selecting the forward sweep time charging capacitor. The *fine frequency control* is a potentiometer that allows the adjustment of the sweep circuit time constant to obtain the exact frequency needed to provide a suitable display.

13-20. The selection of different types of horizontal amplifier signals is also determined by the setting of the coarse frequency control. Five or six positions of the coarse frequency control are used to cover the full frequency range of the internal sawtooth sweep generator. Sine-wave signals are widely used for time-base sweep applications. Such signals are easily obtained from the 60-hertz power source within the oscilloscope. This 60-hertz, or line sweep, signal is usually available at the coarse frequency control, but some oscilloscopes provide this signal from a separate terminal. In some applications, the 60-hertz signal is not suitable for the best display. A "direct" position is provided on the coarse frequency control to permit the use of sine waves at frequencies other than 60 Hz and to display waveforms resulting from time bases other than those available within the scope. The sawtooth sweep generator is disabled by the coarse frequency control when either the line sweep function or the direct function is selected.

13-21. The fine frequency control, in conjunction with the coarse frequency control, permits you to select the time base required to display as many cycles or pulses as desired to view the waveform under investigation. This control is uncalibrated, except for markings which permit you to estimate some previous position. Calibration of this control is not required because you are not actually interested in the time-base frequency, except as a means of obtaining a convenient display. The frequency of the time-base sweep generator can be easily determined by injecting a known frequency into the vertical amplifier and then manipulating the coarse and fine frequency controls for a stationary pattern of one complete cycle. Under these conditions, if the injected signal is a sine wave of 1000 Hz, then one sine wave lasting 1/1000th of a second is displayed by one sawtooth wave, also lasting for 1/100th of a second. Therefore, the frequency of the time-base sweep generator is also 1000 Hz and is thus a 1:1 frequency ratio. If the pattern is not stationary, then the method described is not valid and cannot be used with accuracy. It is easy to stop an oscilloscope waveform displayed by use of these controls if the frequency of the waveform under investigation is within the frequency limits of the oscilloscope.

13-22. Thus far, our discussion of the coarse and fine frequency controls has been limited to those cases where the sweep frequency is equal to the frequency of the waveform under investigation. Let us briefly recall two cases where the time-base sweep frequency is lower or higher than the frequency of the waveform applied to the vertical input terminals.

13-23. Whenever two or more complete cycles of an input waveform are displayed, whether stationary or not, the frequency of the time-base sweep generator is lower than that of the input waveform. When the display is adjusted for a stationary pattern, the frequency of the time-base generator may be calculated, if the input frequency is known, by dividing the input frequency by the number of complete cycles displayed.

13-24. Many apparently odd and unusable patterns are displayed on the oscilloscope when the frequency of the time-base sweep generator is higher than the frequency of the waveform under investigation. Such patterns are not entirely unusable since they may convey useful information to the observer.

13-25. Assume you have a sine-wave input signal of 60 Hz to the vertical amplifier. At the same time, the time-base generator is furnishing a sweep signal to the horizontal amplifier at 120 Hz to give a stationary display. Refer to figure 46,A. One complete sweep of the time-base generator displays only one-half of the sine wave before returning to the left-hand side of the scope viewing area. If the sine wave starts from zero toward its maximum value at the same instant that the time-base generator starts sweeping from its zero value, then the entire positive portion of the sine wave (points *a*, *b*, and *c*) is displayed during this sweep. As the generator once more initiates its sweep, the sine wave is at its zero point, going toward its maximum negative value. The display at the end of this second sweep shows one complete sine wave, with the positive half positioned over the top of the lower half.

13-26. Now assume that the sawtooth sweep is initiated at point *b*, the maximum positive value of the sine wave, at the same instant that a sweep is initiated. A second stationary pattern, as shown in figure 46,B, can be obtained under similar conditions by changing the phase of the 60-hertz sine-wave input with respect to the sweep of the time-base generator.

13-27. The entire positive-to-negative alternation of the input waveform is displayed during the first sweep of the time-base generator. After being returned to the left-hand side of the viewing area during the retrace period, the sweep is initiated for the second time to display negative-to-positive alternation of the sine wave. Once again, the time-base

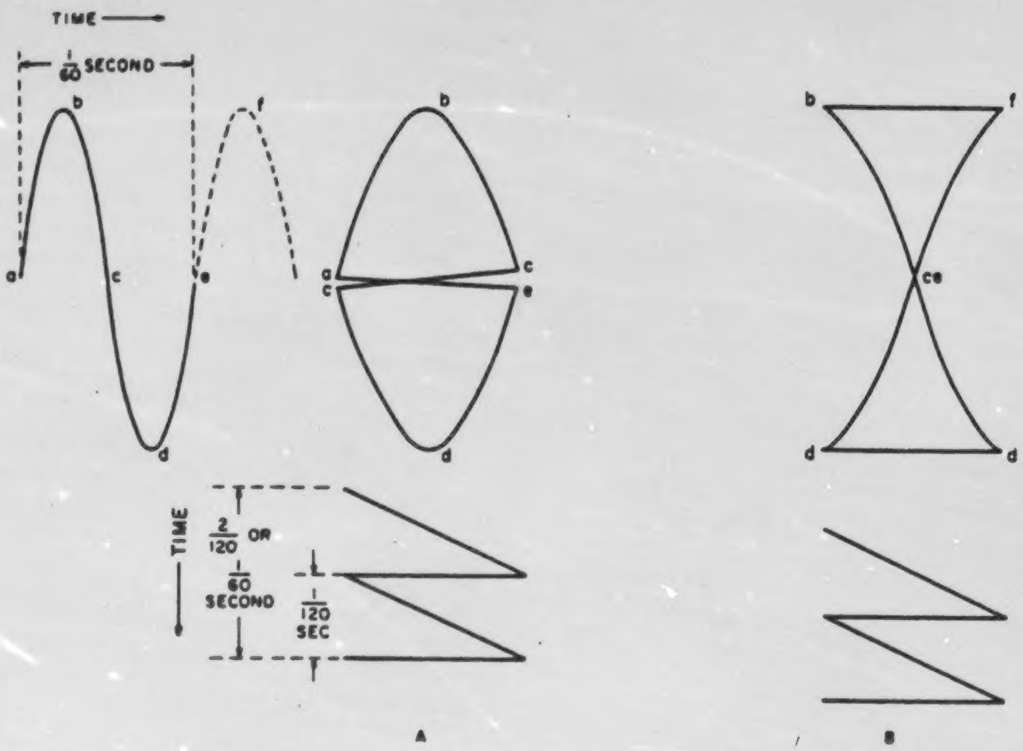


Figure 46. Patterns when sweep-to-signal ratio is 2:1.

generator has used two sweeps to display one complete cycle of the input waveform.

13-28. In either case cited, the input waveform has been "chopped up" into two segments for the display. Figure 47 shows the stationary displays presented by an oscilloscope for a vertical-to-horizontal frequency ratio of 1:3. The 1:3 ratio is shown for two different phase relationships. These traces may also be inverted, depending again upon the phase relationships between the two signals.

13-29. *Synchronizing.* The synchronizing control found on all oscilloscopes permits a portion of the signal being amplified in the vertical section to be injected into the time-base generator for the purpose of producing a stationary waveform display.

13-30. Throughout our dicussion about time-base sweep controls, we have emphasized the stationary display. A signal supplied to the vertical amplifier which bears some integral frequency and phase relationship to the signal produced by the horizontal amplifier produces a stationary display. A consideration of the frequency tolerances and stability characteristics of electronic equipment, in general, shows that it is improbably to consistently maintain these frequency and phase requirements. Therefore, the synchronizing control is included as a part of the oscilloscope circuitry to obtain a stationary display for a detailed waveform investigation.

13-31. A potentiometer is used as the synchronizing control, to permit you to inject as much of the synchronizing signal as necessary to produce a stationary display pattern. The adjustment of this control is not critical, but the use of too much synchronizing signal can cause severe distortion of the observed signal. This is due to erratic functioning of the time-base generator.

13-32. If the synchronizing control is advanced too far, the amplitude of the synchronizing signal produces a distorted sweep signal. Inspection of figure 48 reveals that the excursion of the injected signal has initiated two sweeps per cycle of the applied signal. Under these conditions, the resultant time base was plotted against the applied signal produced by the vertical amplifier to obtain a graphical representation of the scope display, as shown in figure 49. The display is undesirable in this form because it is difficult to visualize the type of signal applied at the vertical input terminal. Despite the undesirable double

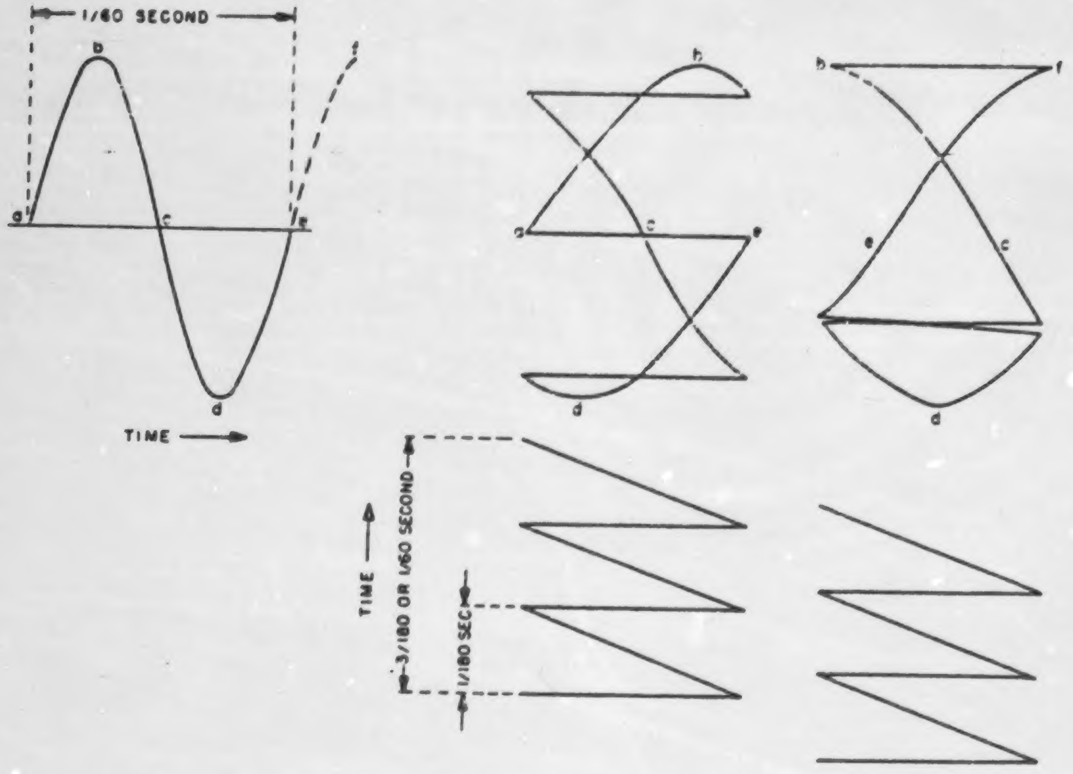

1/60 SECOND
a
b
c
d
e
f
TIME →
TIME →
3/180 OR 1/60 SECOND
1/180 SEC

Figure 47. Patterns when sweep-to-signal ratio is 3:1.

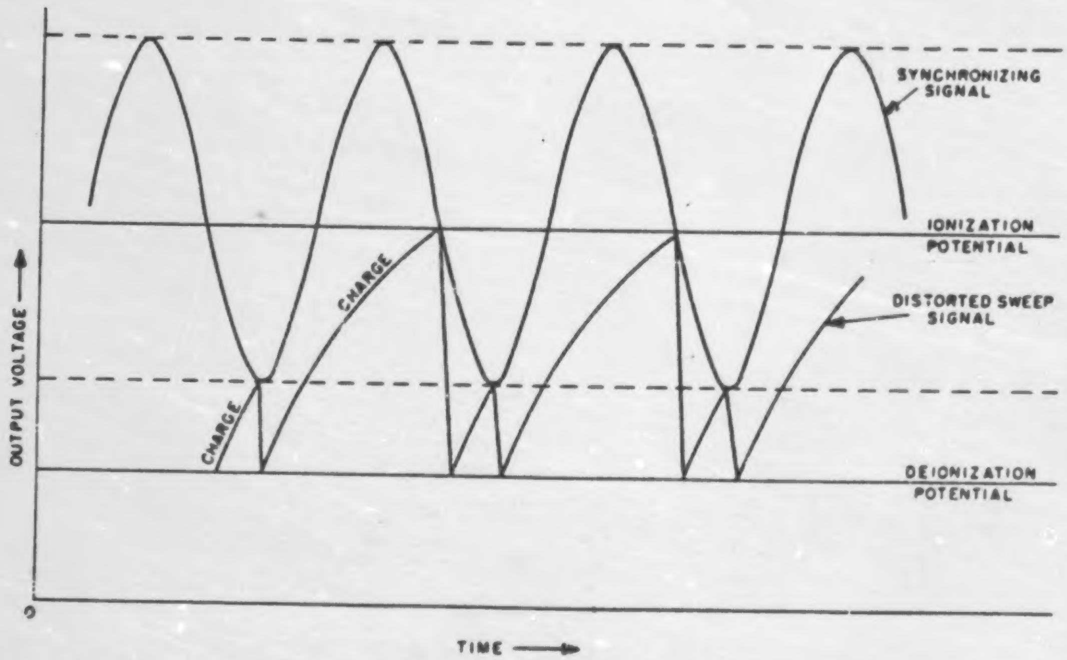

SYNCHRONIZING SIGNAL
IONIZATION POTENTIAL
CHARGE
DISTORTED SWEEP SIGNAL
CHARGE
DEIONIZATION POTENTIAL
OUTPUT VOLTAGE →
0
TIME →

Figure 48. An effect of excess synchronizing signal upon the sweep.

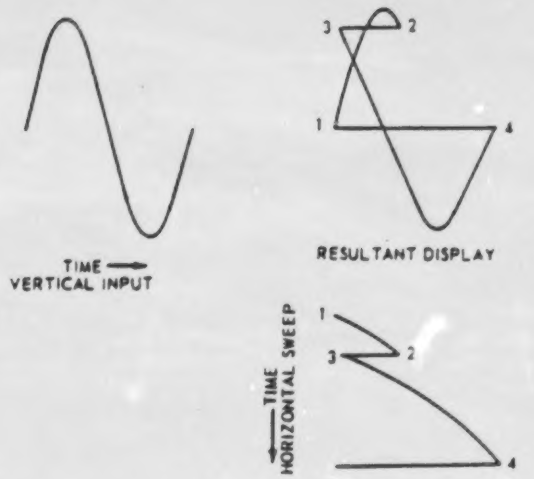


Figure 49 Display resulting from a distorted stable sweep.

sweep, inspection of the resultant time base with respect to the synchronizing signal shown in figure 48 shows that the repetition rate of the time-base signal remains constant. The pattern remains stationary, being continuously displayed as a signal trace, until corrective action is taken.

13-33. Another example of excessive synchronizing signal amplitude is shown in figure 50 and 51. Investigation of figure 50 shows how the frequency of the time-base generator has become unstable because of incorrect sychronizing control adjustment. Note that the amplitude and length of the linear sweep are different for each sawtooth. This time base is plotted against the signal output from the vertical amplifiers to obtain the resulting display shown in figure 51.

13-34. The synchronizing signal may be injected directly into the time-base generator from a source external to the scope. The need for external sync depends chiefly upon the type of signals undergoing observation.

13-35. *Intensity modulation.* Many scopes provide an external terminal for the injection of a signal directly into the cathode-ray tube, through its grid or cathode circuit, to modulate the moving electron beam. This terminal is called by one of two common names—*Z-axis input* or *intensity modulation input.*

13-36. Variation of the grid-to-cathode potential changes the density of the electron beam within the cathode-ray tube and in this manner determines the intensity of the light emitted from the fluorescent screen.

13-37. Although any type of waveform produces intensity modulation, the preferred type of signal is in the form of sharp pulses to permit precise measurement of the time interval between pulses. These pulses, termed *markers,* should be of short duration with a high repetition rate with respect to the signal being examined. The resultant display on the cathode-ray tube will have a number of alternate bright or dark spots corresponding to

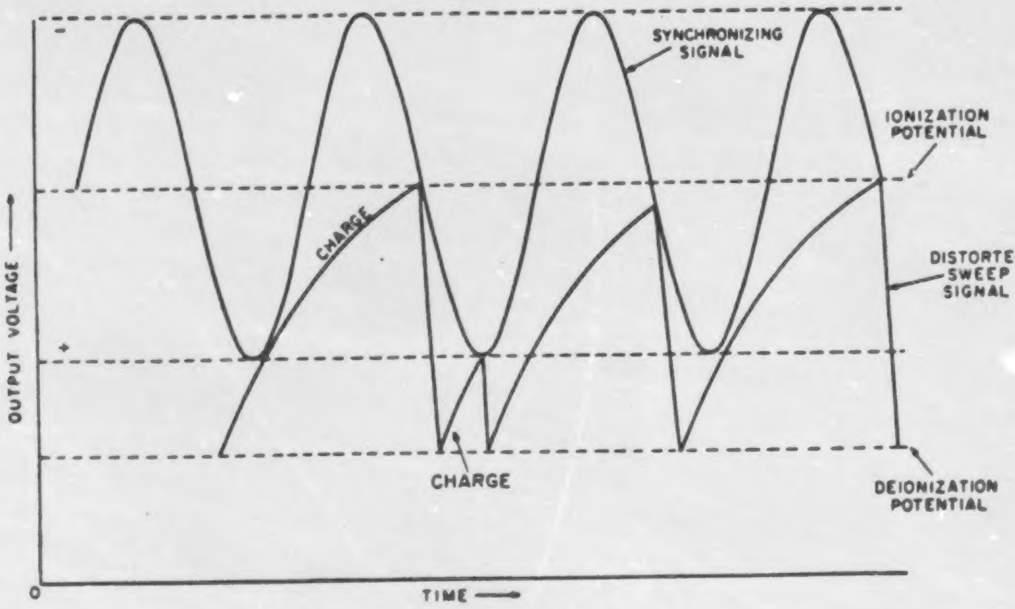


Figure 50. Distorted sweep caused by improperly adjusted sync.

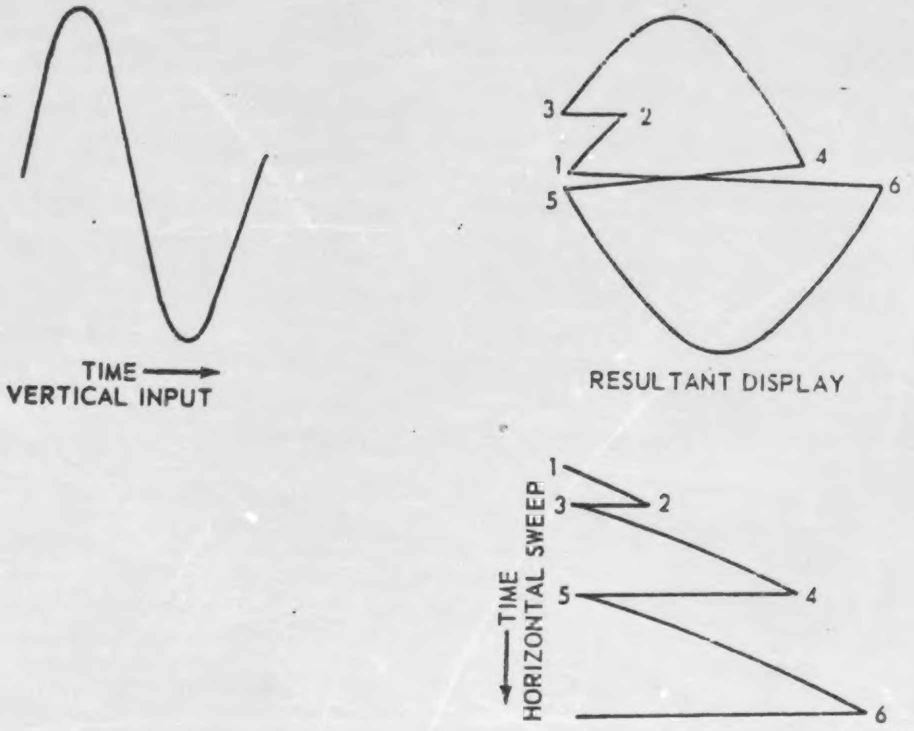


Figure 51. Display resulting from a distorted unstable sweep.

the occurrence of the markers, depending upon whether they increase or decrease the beam intensity.

13-38. If the marker signal is introduced at the grid of the cathode-ray tube, negative pulses cut off the electron beam so that no trace is produced; during the next interval, the beam is permitted to stroke the fluorescent screen to produce a normal intensity spot. If, on the other hand, the marker pulses are positive, the beam intensity is increased so that a trace of increased brilliance can be observed; during the next interval, the beam is returned to normal intensity. The amplitude of the marker signal is relatively unimportant, except that the amplitude of the negative marker signals must be sufficient to drive the grid of the cathode-ray tube to cutoff. When the marker signal is produced at the cathode of the display tube, the polarity of the marker signals must be interchanged to maintain the conditions presented in the preceding paragraph.

13-39. In most scopes that provide this feature, the intensity modulation circuit is a simple RC network. The frequency of the marker signal must lie within the passband of the Z-axis circuit, or frequency discrimination in the form of signal differentiation will take place.

13-40. The input terminal for the Z-axis is not always located on the front panel of the oscilloscope. It is often found on the rear chassis apron.

13-41. **Operating Considerations.** The oscilloscope and synchroscope are subject to limitations and malfunctions, just as any other electronic device. Although some precautions for scopes have been previously stated or implied, we also include them here for added emphasis and convenience.

13-42. *Precautions.* When you use oscilloscopes, it is advisable never to operate an oscilloscope with the case removed, since high voltages are exposed that can cause fatal shock. Removal of the case also reduces shielding of the instrument from stray external fields.

13-43. Extreme caution should be exercised by personnel handling cathode-ray tubes. The glass envelope incloses a high vacuum; undue stresses and rough handling can cause serious injury, due to tube implosion. The fluorescent coating of the cathode-ray tube is extremely toxic. When handling broken cathode-ray tubes, avoid contact with this material.

13-44. Remember that a bright spot must not be permitted to remain in a stationary position on the fluorescent screen; the energy of the electron beam concentrated in a small area will burn the screen coating. Remember also to provide a good bonding between the oscilloscope, operating equipment, and ground. Grounding is a good general practice to eliminate electrical shock hazards and to produce clear displays that are free of stray noise signals. Ground connections can be greatly improved by placing the equipment being tested, the oscilloscope, and other accessory equipment on a large sheet of conductive material insulated from the workbench top. A single connection between the metal sheet and ground can then be made. There is usually an exception to any rule, and those circuits that operate above ground are the exception. When dealing with this type of circuit, (1) insulate the oscilloscope from ground, (2) use caution during measurement, and (3) break the connection as soon as the measurement is completed.

13-45. Know the operating condition of your scope and other test equipment. Maintenance routines using a signal generator and a scope are misleading and inconclusive if either or both test equipments are causing, or contributing to, a faulty display.

13-46. Input impedances of oscilloscopes are generally high enough to produce negligible loading of the circuit under observation; so impedance matching is seldom required. However, the input impedance of the scope must be higher than or equal to the impedance of the circuit under investigation if detuning and loading effects are to be avoided. Technical manuals supplied for scope maintenance usually state this impedance in terms of a resistance shunted by a capacitor. Low-impedance coaxial cables are often used in pulse maintenance engineering techniques. It is imperative in these cases to consider the types, lengths, and input impedances of the connecting leads. High-impedance frequency-compensated probes are often provided as accessories for the oscilloscope to prevent any loading and detuning effects of resonant high-frequency circuits. These probes are discussed later in this chapter.

13-47. Oscilloscope test leads should be adequately shielded to prevent undesired coupling effects. The lengths of open wire leads and their attendant stray capacitance to ground, coupled with a high input impedance, can cause the oscilloscope amplifiers to develop an appreciable display from random or stray signals. The shielding of the test leads should be connected to the ground terminals adjacent to their input terminals to prevent interaction of common impedance ground loops between different terminal points on the scope panel. This is especially important when observing pulses, while using external synchronizing and triggering cables; otherwise you risk erratic triggering of the sweep generator.

13-48. Voltages which overload the input circuits of the oscilloscope should not be applied to the input terminals. This precaution applies to the external synchronizing and Z-axis input terminals as well as the vertical and horizontal input terminals. Vertical and horizontal amplifiers often contain an attenuator to provide control over large amplitude signals, but many of these same oscilloscopes do not provide similar controls for the synchronizing or Z-axis input channels. When working with large amplitude signals at oscilloscope inputs lacking attenuators, wrap the insulated test lead around the input terminal concerned to provide sufficient coupling.

13-49. Some oscilloscopes provide a second vertical input terminal connected by a strap to the oscilloscope ground terminal. The purpose of the two vertical input terminals is to provide for the observation of balanced signal sources; the strap is used to ground the unused terminal during inspection of single-ended amplifiers.

13-50. *Malfunctions.* Malfunctioning circuitry within the oscilloscope can cause erratic and faulty displays, or it can cause difficulties in the manipulation of various operating controls. Potentiometers used as the variable amplitude control of vertical and horizontal amplifiers develop small scratches in the resistive element or on the rotor contact from small abrasive particles contained in dust. As the rotor moves over the marred resistive element, noise signals are generated, creating a display which is extremely ragged in appearance and which may or may not bear some resemblance to the original input signal. The characteristic "grass" display resulting from noise signals may disappear as soon as the control is released, continuing the display of the original input signal. On the other hand, the "grass" display may persist, indicating poor contact between the rotor and the resistive element at that point. Other causes of noise displays are poor input connections and microphonic amplifier tubes.

13-51. The input impedance of the first amplifier is quite high, making the oscilloscope susceptible to stray external signals. External fields, especially at powerline frequencies, can be picked up by unterminated oscilloscope

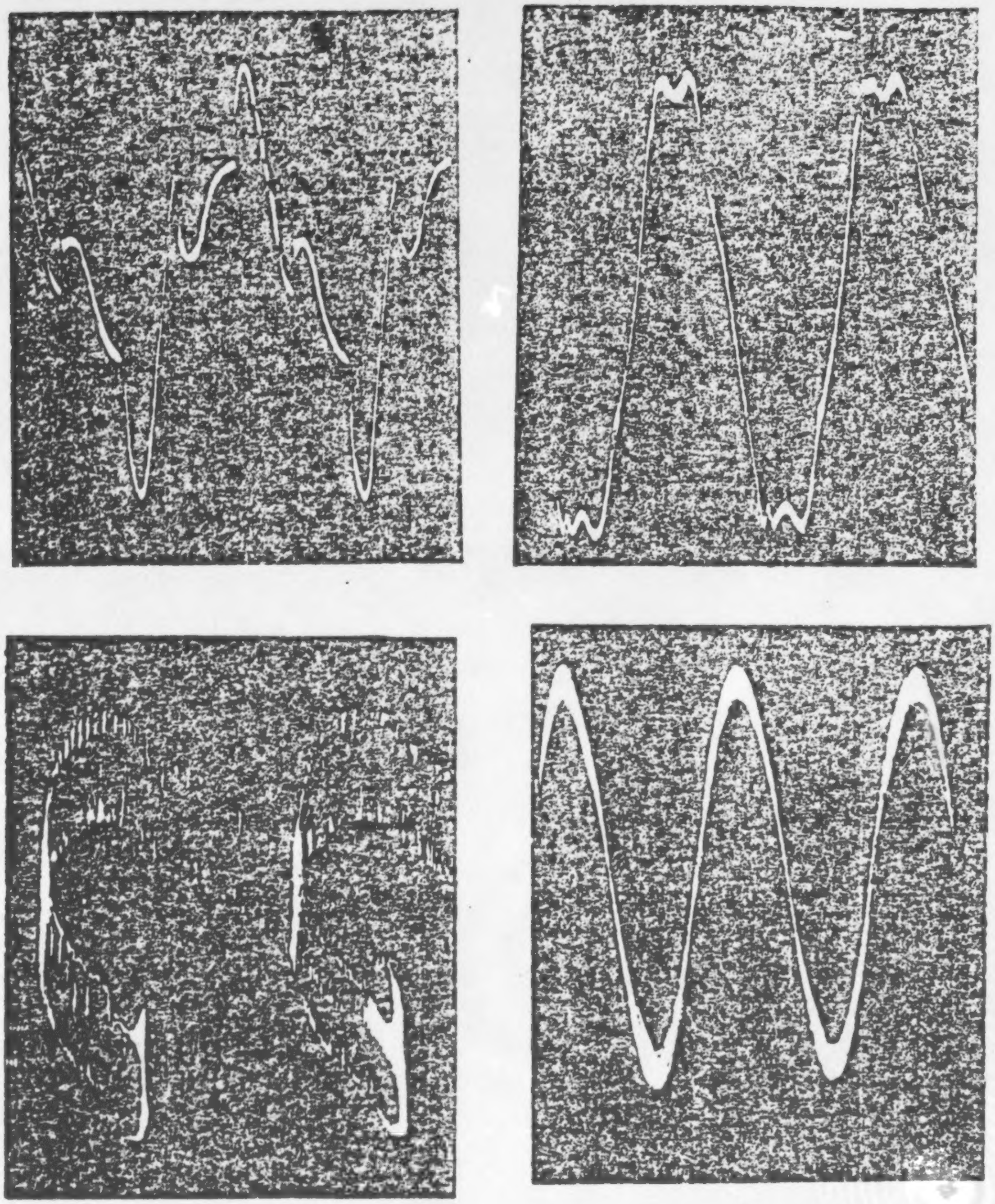


Figure 52. Distorted displays caused by hum

leads. Similarly, rectangular waves in the vicinity can be picked up and are usually mixed with stray powerline displays (see fig. 52). Displays of this nature should not cause any difficulty, because they are usually eliminated when the scope is connected to the circuit under test. However, hum signals from power transformers, chokes, and soldering irons may be strong enough to affect the display, even though connection is made to the circuit under observation. Figure 53 is an example of the effect these devices can have upon the display of sine waves.

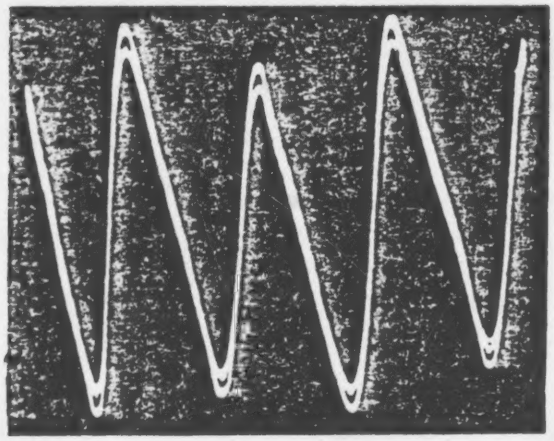


Figure 53. Distortion caused by low-frequency hum.

14. A Typical Oscilloscope

14-1. Now that you have learned the basic principles of an oscilloscope, let's study the waveform interpretation and controls of a typical multitrace oscilloscope. The functional circuits and front panel controls of most oscilloscopes are very similar. Therefore, we explain only the functions and controls of a model commonly used in communications and electronics maintenance.

14-2. Figure 54 is a front panel view of the Tektronix 585A with type 82 plug-in unit installed. Like most test equipment, it is composed of numerous sections and subsections which have specific functions to perform. As each section is discussed, all front panel controls associated with that section are also discussed. Throughout this discussion you will be referred to figure 54 to locate the controls.

14-3. **Sweep Generation and Synchronization.** The versatility of any oscilloscope depends largely upon its sweep and sweep synchronization circuits. To obtain a stable presentation, the sweep circuits must be able to produce a sweep voltage that is in sync with the displayed signal. The sweep generator must also be able to produce a sweep voltage beginning at selected times with respect to the vertical signal. If the sweep generator can do these things, then it is possible to present any desired part of the vertical signal on the CRT indicator. Some oscilloscopes accomplish these functions by using dual-sweep generators that can operate either separately or in conjunction with each other. To show these principles, let's use the oscilloscope shown in figure 54. The HORIZONTAL DISPLAY switch on the upper right front of this oscilloscope is used to select the desired sweep function. These functions, reading counterclockwise around the control from 2 o'clock, are as follows:

- "A" SINGLE SWEEP.
- "A" SWEEP.
- "A" SWEEP DELAYED BY "B" SWEEP.
- "B" SWEEP INTENSIFIED BY "A" SWEEP.
- "B" SWEEP.
- EXTERNAL SWEEP (UNATTENUATED - X1).
- EXTERNAL SWEEP (ATTENUATED - X10).

Let's discuss these in the order of most frequent use, starting with the A SWEEP.

14-4. *A sweep.* When this sweep function is selected, the A sweep generator and its associated circuits function independently of the B sweep. the A sweep circuit is made up of these units:

- A synchronized sweep trigger generator.
- A sweep generator.
- A horizontal sweep amplifier.

14-5. The trigger generator generates the trigger for the sweep generator. This trigger is synchronized by the signal being displayed by a 6.3-volt AC line signal, or by an external sync signal. When using this type of oscilloscope, it is up to you to decide how the sweep can be most effectively synced and then set the associated front panel control to the desired trigger source position. Now let's discuss the factors that must be considered when making this decision.

14-6. To analyze a waveshape, we must be able to see it clearly. Without sweep synchronization, you can see the signal but in most cases it is nothing but a blur. An indiscriminately triggered sweep starts without regard to time displacement of the signal being displayed. Each succeeding sweep starts at a different relative time with respect to the signal on the vertical deflection plates. This causes the signal to appear to run across the face of the indicator. Figure 55 is an example of an unsynchronized display of a uniform sine wave. The running effect can be eliminated by adjusting the sweep frequency until it is the same as or an exact multiple of the vertical signal; however, this method is impractical since even the slightest signal variations require readjustment of the sweep frequency. If the sweep is started at exactly the same point with respect to the vertical signal, each trace

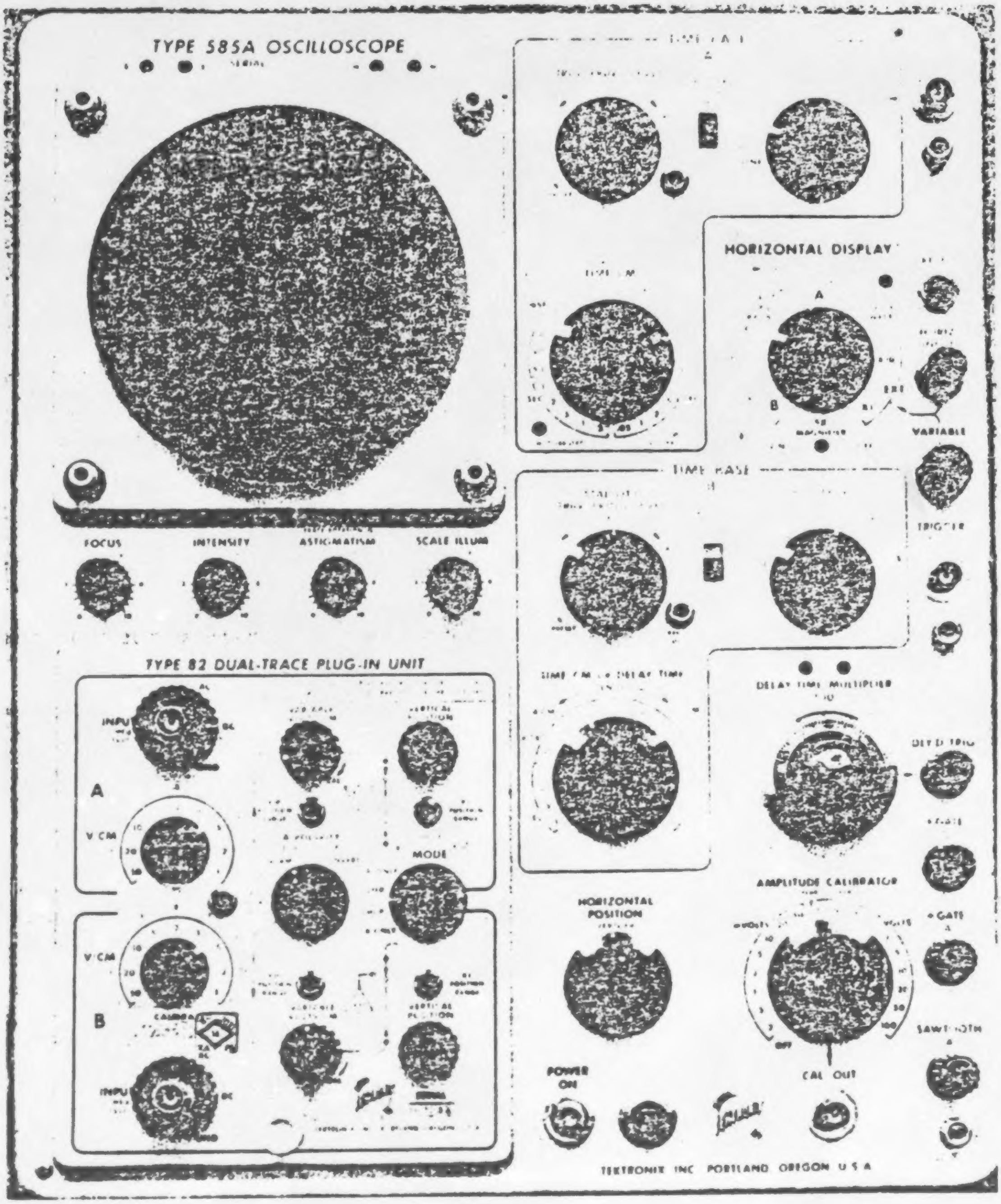

TYPE 585A OSCILLOSCOPE
SERIAL
TIME BASE
A
TIME/CM
HORIZONTAL DISPLAY
A
B
VARIABLE
TIME BASE
B
TRIGGER
FOCUS
INTENSITY
ASTIGMATISM
SCALE ILLUM
TYPE 82 DUAL-TRACE PLUG-IN UNIT
INPUT
DC
A
V/CM
MODE
V/CM
B
INPUT
DC
TIME/CM OR DELAY TIME
DELAY TIME MULTIPLIER
DLY'D TRIG
+GATE
AMPLITUDE CALIBRATOR
HORIZONTAL POSITION
+GATE
A
SAWTOOTH
A
POWER ON
CAL OUT
TEKTRONIX INC PORTLAND OREGON U S A

Figure 54. The Tektronix 585A oscilloscope.

presents the exact same portion of the vertical signal. This action is shown in figure 56. Note that each time the sweep occurs, the same portion of the vertical signal is traced on the indicator. To obtain this type of sweep, the oscilloscope sweep generator is triggered by (1) an external signal of a frequency that is equal to or a multiple of the vertical signal or (2) by the vertical signal itself. Now let's see how this is accomplished.

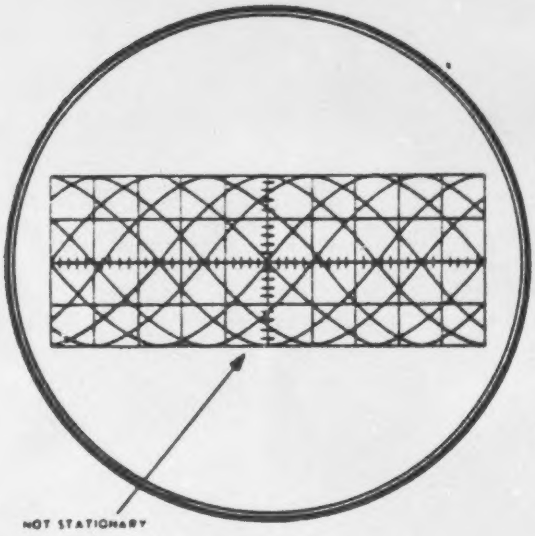


Figure 55. Unsynchronized sine-wave display.

14-7. The oscilloscope shown in figure 54 can be synchronized by a line, internal, or external signals, depending on the setting of the TRIGGERING SOURCE switch (upper right). In the INTERNAL SYNC positions, a sample of the input signal is taken from the vertical amplifier; in the EXTERNAL SYNC positions, a sample is taken from an external sync signal that is connected to the TRIGGER INPUT jack (fig. 54, upper right); and in the LINE position, the oscilloscope 6.3-volt, 60-hertz filament signal is used.

14-8. At this point it is important to remember that the sync signal selected by the TRIGGERING SOURCE switch does not trigger the sweep generator but triggers the trigger generator, which in turn produces a trigger for the sweep generator.

14-9. Now let's look a little deeper and see what happens under the various triggering conditions. When the TRIGGERING SOURCE switch is in one of its INTERNAL positions, a sample of the input signal is taken from the vertical amplifier and fed as an input to the trigger generator circuits. The first thing that the trigger generator does to the input signal is set its reference level. This level is determined by the setting of the TRIGGERING LEVEL control (see fig. 54, top center). Figure 57 shows the input signal at four different reference levels ranging from maximum negative (Level A) to maximum positive (Level D). The triggering level line shown in figure 57 is the reference level that the input signal must cross for the trigger generator to produce a sweep trigger. Now let's see what happens when the TRIGGERING LEVEL control is set to each of the four reference levels shown in figure 57.

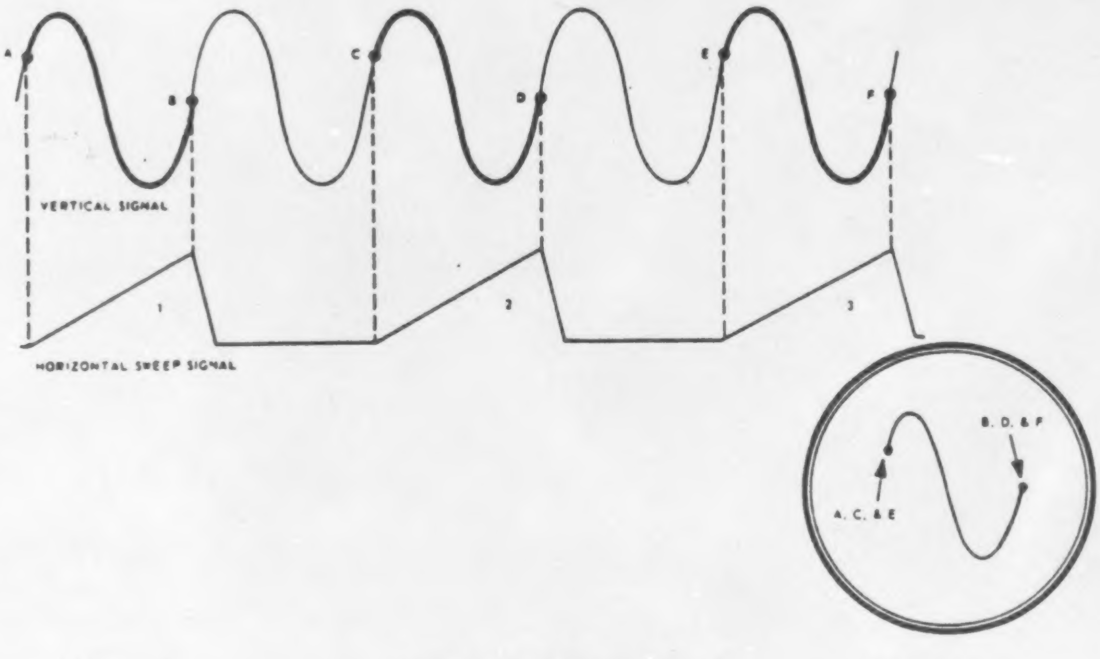


Figure 56. Synchronized display.

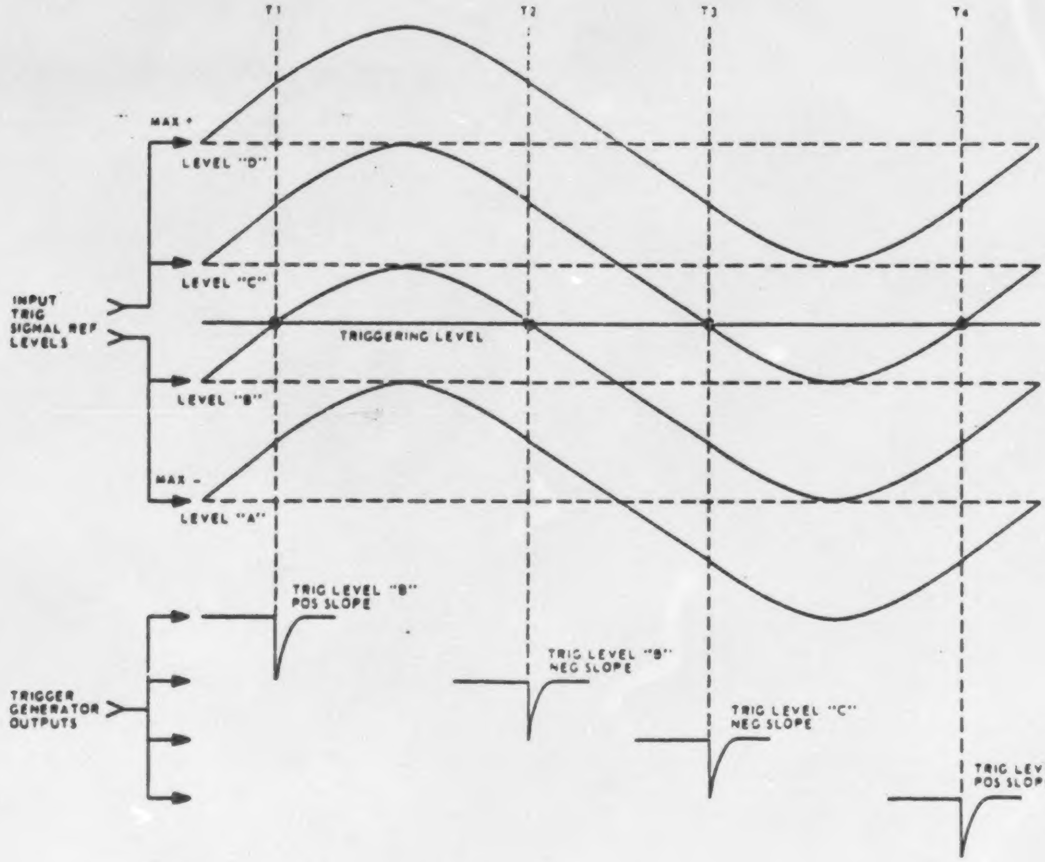


Figure 57. Effects of triggering level and slope control.

- Level A. This reference level is obtained by setting the level control to its maximum negative position. Note that as the signal alternates above and below this reference level, it never crosses the triggering level and thus no sweep trigger is generated.
- Level B. As the level control is turned in the positive direction, reference level B is obtained. With this reference level setting, you can see that the triggering level is crossed at time T1 and at time T2. Now, to obtain a stable sweep for any given signal, we do not want to develop sweep triggers at more than one point on the signal. Look again at figure 54 and note the TRIGGER SLOPE switch. It is the toggle switch located between the TRIGGERING LEVEL and TRIGGERING SOURCE controls. With this switch in the positive position, the trigger generator produces a trigger only on the positive slope of the input signal as it passes the triggering level (T1). For this same signal and with the switch in the negative position, a sweep trigger is produced at T2. The trigger and the conditions under which the trigger is generated are shown below each trigger point, T1, T2, T3, and T4, in figure 57.
- Level C. Now assume that you change the TRIGGERING LEVEL control to obtain signal reference level C. As the signal alternates above and below reference level C, it crosses the triggering level at times T3 and T4. If the SLOPE control is set to its positive position, the sweep trigger is produced at T4. With the SLOPE control in its negative position, the sweep trigger is produced at T3.
- Level D. Setting the TRIGGERING LEVEL control to its maximum positive position results in the signals' riding reference level D. Once again the signal never crosses the triggering level and no trigger is produced.

14-10. Now you should be able to come to an important conclusion; that is, to insure that a sweep trigger is generated, the initial setting of the TRIGGER LEVEL control should be at or near midrange.

14-11. Now let's assume that you do not

wish to trigger the sweep with the vertical signal. In this case you must use either the EXTERNAL or LINE positions of the TRIGGERING SOURCE switch. In each of these positions, the trigger generator functions the same as it did in the INTERNAL position. When using these positions, you must remember that to obtain a stable presentation the sweep triggers must be produced at the frequency of or at a frequency that is a multiple of the signal being displayed. Because of its 60-hertz frequency, the LINE SYNC position has little practical value except in cases such as checking for ripple in power supplies or hum in signal lines. External sync, however, is frequently used when troubleshooting or signal tracing. In many equipments a master timing signal is used to produce all other signals. It is therefore convenient to connect this signal to the TRIGGER INPUT jack (fig. 54, upper right corner) for use as an external sync signal. When you are testing signals from different points in the equipment where signal amplitudes and shapes vary, the use of a standard sync signal eliminates the necessity for continual readjustment of the triggering controls.

14-12. Another factor to be considered when synchronizing the trigger generator is the frequency of the sync signal. Wide variations in sync signal frequencies require adjustments in the input circuits of the trigger generator. Look again at the TRIGGERING SOURCE switch in figure 54. Note that there are three internal and three external positions. These different positions adjust the trigger generator input circuits for various frequencies of input signals. In either of the high-frequency sync positions (HF SYNC), the trigger generator circuits couple the sync signal directly to the sweep generator for use as a sweep trigger. In all other positions the trigger generator functions as discussed in the previous paragraphs.

14-13. Before going on to the sweep generator, let's summarize. The trigger generator produces a trigger for the sweep generator. The TRIGGER LEVEL and SLOPE controls are set to produce this trigger when the sync signal is at the desired level and swinging in the desired direction. The sync signal must have a definite frequency relationship to the vertical signal in order to produce a stable trace.

14-14. A typical sweep generator may consist of a sweep multivibrator, a Miller integrator, a holdoff cathode follower, and a trigger gate interconnected, similar to the generator shown in figure 58. Normally, you will find that the multivibrator is a bistable type and changes state only when triggered. With this type of sweep multivibrator, it is possible to start and stop the sweep at specific times.

14-15. When a trigger is received from the trigger generator, the state of the sweep multivibrator changes, and a negative level pulse is coupled to an RC network in the grid circuit of the Miller integrator. The charge rate of the capacitor in the RC network is held constant by a feedback between the plate and grid circuits of the integrator; thus the integrator produces a very linear sawtooth which is coupled to the horizontal amplifiers. The sawtooth output of the integrator is also coupled to the holdoff circuit. This circuit is adjusted so that when the integrator output reaches a required level (this level is a function of the indicator deflection factor and the physical length of the sweep desired), the output of the holdoff circuit retriggers the sweep multivibrator back to its normal resting state. The sweep is thus terminated and will not start again until the next trigger is received from the trigger generator.

14-16. Before going on, there are two important points you should remember:

(1) The generator is set to produce a sawtooth of a specific amplitude. The TIME PER CENTIMETER control (fig. 54, just to the right of the indicator) varies with the rate of charge, not the amplitude.

(2) When using the scope, if you notice that the sweep is not of the proper physical length, first check to see if the sweep generator output is the correct amplitude. If it is not, your problem may be only an improper feedback adjustment. This adjustment is usually made by an internal sweep length control such as the one shown in figure 58.

14-17. Now look at the trigger gate block shown in figure 58. This block controls the bias on the sweep multivibrator when it is at rest. When operating the scope in the A SWEEP function, the trigger gate is controlled by the STABILITY control (fig. 54, top center, small knob). The STABILITY control sets the bias on the trigger gate, which in turn controls the bias on the sweep multivibrator. To set the STABILITY control, you perform the following steps:

(1) Set the control fully counterclockwise.
(2) Turn control clockwise until a sweep first appears.
(3) Turn control counterclockwise again until the sweep just disappears.

Now the sweep multivibrator can be triggered as soon as a signal is connected.

14-18. To see more clearly how the sweep generator works, you should be able to visualize what is happening at each of the major signal points. Let's assume that a sine-wave signal is applied to the vertical input of the oscilloscope. You set the TRIGGERING SOURCE switch to the proper internal position, the TRIGGER SLOPE switch to negative, and the TRIGGERING LEVEL to 0 volt. Under these conditions, the sweep starts when the negative alternation is applied to the vertical plates.

14-19. Look now at figure 59 and see how the sweep circuits accomplish this. Waveshape A is the vertical input signal, and waveshape B is the same signal applied to the input of the trigger generator. With the controls set as stated in the previous paragraph, the trigger generator produces sweep triggers (signal C) each time its input (signal B) passes through zero in a negative-going direction (points 1, 2, 3, and 4). The first trigger is applied to the sweep multivibrator and causes its output to go negative (signal D). During the time the sweep multivibrator output is negative, the sweep generator output rises at a linear rate (signal E). Part of the sweep signal is fed to the holdoff circuit, where it causes the output of the holdoff circuit to rise (signal F). The output of the holdoff circuit is the bias on the sweep multivibrator. When signal F reaches point X, the sweep multivibrator is retriggered back to its resting state and the sweep is terminated. The sweep circuits remain at rest until the next trigger is received from the trigger generator (signal C, pulse # 3) and the same actions are repeated. The darkened areas of the input signal (signal A) are thus traced on the indicator as the presentation shown at H in figure 59.

14-20. You may wonder how the indicator is blanked during retrace time. In the scope in figure 54, for example, the indicator is normally biased to cutoff and is allowed to conduct only when sweeping. This is done by taking the positive output of the sweep multivibrator and coupling it to the CRT as an unblanking signal (signal G, fig. 59). Since the sweep multivibrator determines sweep length and the unblanking signal is of the exact same duration as the sweep, only the sweep is visible.

14-21. Let's go back now and discuss the TIME PER CENTIMETER control in a little more detail as it applies to period and frequency measurements. As a maintenance man you will measure pulse widths, periods, frequencies, and any other events that may be a function of time. The TIME PER CENTIMETER control indicates exactly what its name implies; that is, it indicates the time required for the electron beam to deflect 1 centimeter horizontally. It is relatively simple for you to determine the number of centimeters that the beam is deflected horizontally and then, with a little mathematics (number of

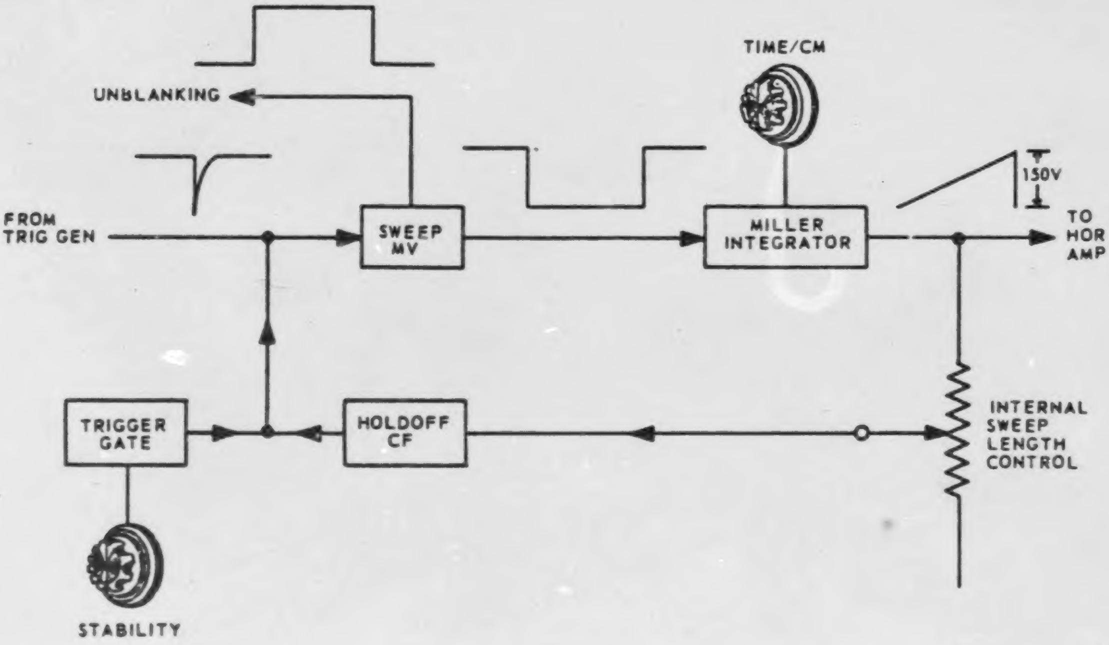


Figure 58. Sweep generator

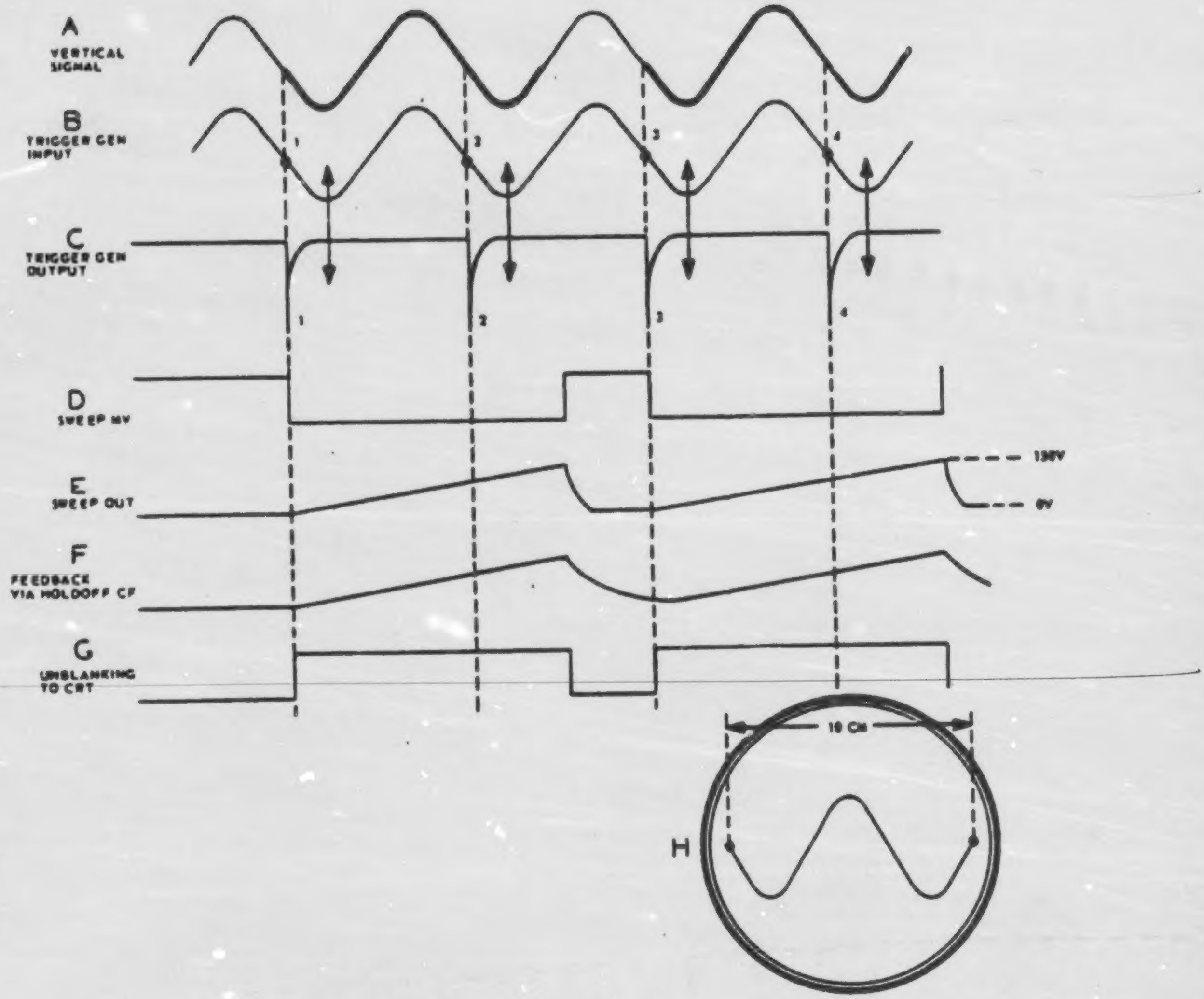

A
VERTICAL SIGNAL
B
TRIGGER GEN INPUT
C
TRIGGER GEN OUTPUT
D
SWEEP MV
E
SWEEP OUT
F
FEEDBACK VIA HOLDOFF CF
G
UNBLANKING TO CRT
1
2
3
4
130V
0V
10 CM
H

Figure 59. A sweep generation and display.

centimeters times the setting of the TIME PER CENTIMETER control), determine the time for any event associated with the display signal. As for frequency measurements, frequencies can be readily determined by use of the following formula:

$$\text{Frequency} = \frac{1}{\text{time per cycle}}$$

14-22. For an example of frequency measurements, look at figure 60. Here a 50-kHz sine wave is an input to the oscilloscope shown in figure 54. The TRIGGER LEVEL and TRIGGER SLOPE controls are set to develop sweep triggers at the 0-volt level of the negative slope. Now consider three different settings of the TIME PER CENTIMETER control as shown in A, B, and C of figure 60. The sweep length is always 10 centimeters. Frequency determination under these conditions is as follows:

a. The A setting of the TIME PER CENTIMETER control is 1 μsec. Note that 1/2 cycle occupies the full sweep. The time per cycle is 20 μsec. You can calculate the frequency by using the following formula:

$$\text{Frequency} = \frac{1}{\text{time per cycle}}$$

$$\left(F = \frac{1}{t}\right)$$

$$F = \frac{1}{20 \times 10^{-6}} = 50{,}000 \text{ Hz}$$

One trouble encountered with this method of

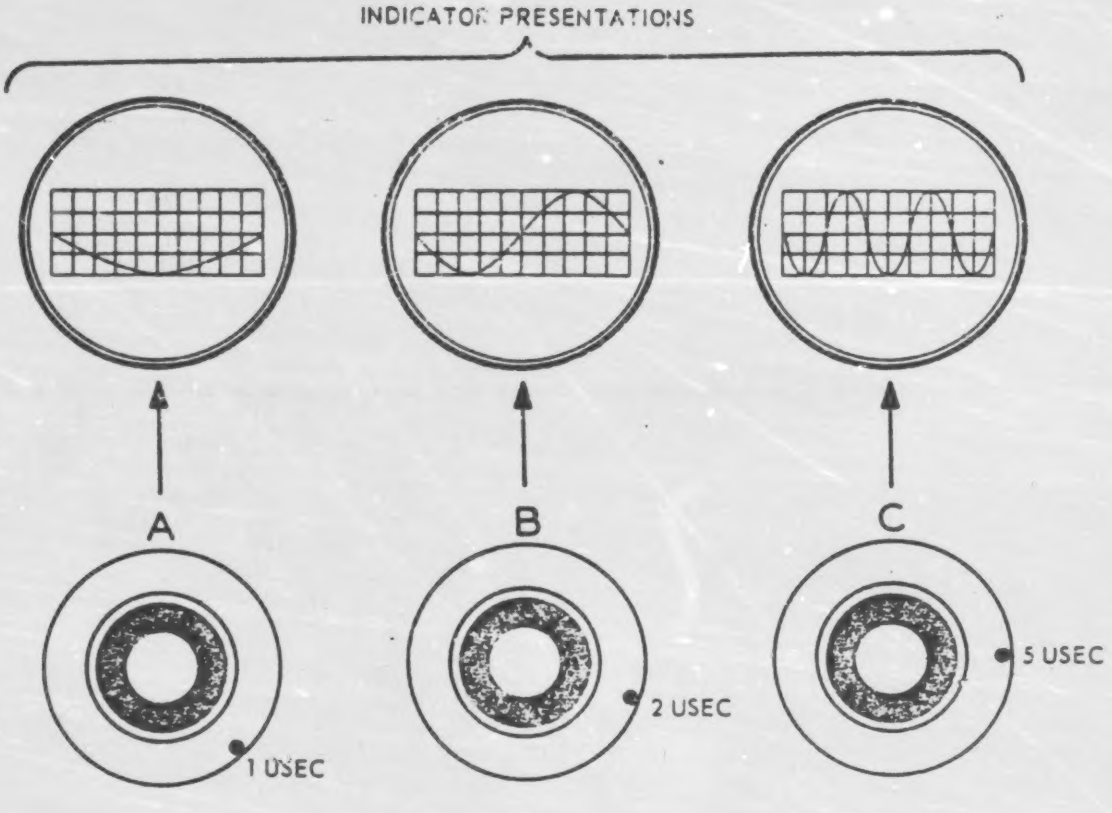


Figure 60. Frequency calculation.

frequency determination is that it is very difficult to determine when the scope displays exactly 1/2 cycle. If you err in determining the time for a half cycle, this error is compounded by doubling the value to determine the time per cycle. When possible, you should *not* use settings of the TIME PER CENTIMETER control that present less than one cycle.

b. The B control setting of 2 μsec results in a one-cycle presentation. Here again it is difficult to determine when exactly one cycle is presented; however, this time the error is not compounded by multiplying.

c. The C control setting of 5 μsec results in a display of 2 1/2 cycles. Here the point at which the signal crosses the zero reference line is much more definite because of the steepness of its slope, and a more accurate calculation can be made.

14-23. There are several ways you can calculate the frequency in this case; the following method is recommended. One centimeter represents 5 μsec; therefore, the full 10-cm sweep represents 50 μsec (5 × 10 = 50). The time for 2 1/2 cycles is then 50 μsec, and the time per cycle is 20 μsec $(\frac{50}{2.5} = 20)$.

$$F = \frac{1}{t} = \frac{1}{20 \times 10^{-6}} = 50{,}000 \text{ Hz}$$

In practice you will find that the most accurate frequency determinations are obtained by setting the time controls for presentations of 2 to 10 cycles.

14-24. *B sweep.* The B SWEEP position of the HORIZONTAL DISPLAY switch shown in figure 54 selects another set of circuits containing a trigger generator and sweep generator that operate similarly to the A sweep and triggering circuits. Look at the B sweep time-base controls in figure 54, and note the similarity to the A sweep time-base controls. Since their functions and operations are similar, it is not necessary to cover them again.

14-25. *"B" intensified by "A."* Until now we have discussed a single sweep function with its associated triggering circuits. Used alone, the addition of another sweep generator and its associated circuits adds nothing to the capability of the oscilloscope. However, when one sweep is used to modify the other sweep, much is added to the scope's capabilities.

14-26. The two sweep generators in the oscilloscope in figure 54 can be triggered by the same synchronizing signal or by separate signals. Regardless of the trigger source, there are two sweep voltages and two unblanking voltages that can be applied to the indicator. This particular scope uses the unblanking voltage of the A sweep to intensity-modulate a portion of the B sweep. The intensified portion may be expanded to give you an enlarged presentation.

14-27. In the "B" INTENSIFIED BY "A" position of the HORIZONTAL DISPLAY switch, the B sweep generator functions normally. When triggered, it develops a sawtooth horizontal sweep voltage and a positive unblanking signal. These signals are coupled to the indicator, and a normal sweep pattern begins. The sawtooth sweep voltage is also sent to a trigger pickoff circuit. The trigger pickoff circuit is set to produce a trigger pulse when the B sweep sawtooth voltage rises to some predetermined (pickoff) point. The bias on the pickoff circuit can be varied so that the pickoff point can occur at any desired amplitude of the sawtooth voltage. In the oscilloscope shown in figure 54, the pickoff point is controlled by the DELAY-TIME MULTIPLIER control. This is the second control from the bottom on the right-hand side. Regardless of the slope of the sweep voltage, it always takes the same voltage to deflect the beam 1 centimeter; therefore, the delay control which sets the voltage of the pickoff point is calibrated in centimeters. The delay time (the time between the beginning of the sweep and the start of the intensified portion) is then calculated by multiplying the setting of the "B" TIME PER CENTIMETER control by the number of centimeters on the DELAY-TIME MULTIPLIER control.

14-28. Now let's see how this sweep intensification works, using a practical example. Look at figure 61. Signal A is a 40-kHz input that is applied as a vertical input and as an input to trigger generator B. Time-base B controls are set as follows: (1) TRIGGERING SOURCE to INT, (2) TRIGGERING LEVEL to 0, and (3) TRIGGER SLOPE to positive. Signal B in figure 61 shows the output of trigger generator B. Note that a trigger is produced when the input signal (signal A in fig. 61) reaches point X. This trigger is fed to the B sweep generator. It initiates a sawtooth sweep voltage (signal C) and a positive unblanking pulse (signal D). The sawtooth sweep voltage and the unblanking pulse are coupled through appropriate circuits to the indicator to unblank and sweep the electron beam horizontally across the scope.

14-29. Before going on, let's assume that the A sweep generator is set for a 5-μsec-per-centimeter sweep, the STABILITY control is fully clockwise, and the B sweep generator is set for a 20-μsec-per-centimeter sweep. Also, assume that the indicator beam is deflected 1 centimeter for every 15 volts of sweep signal (signal C). You have set the DELAY-TIME MULTIPLIER control to 3 1/3 centimeters, which means that the delay pickoff circuit produces a trigger (signal E, fig. 61) when the sweep has moved 3 1/3 centimeters. Now let's look a little closer at how the pickoff trigger is produced. The sweep voltage (signal C) is fed to the pickoff circuit. Remember that the delay time was to be 3 1/3 centimeters. If horizontal deflection takes 15 volts per centimeter, then 3 1/3 centimeters require 50 volts. What the delay control actually does is set the pickoff circuit bias so that the sawtooth (signal C) must rise to 50 volts before the pickoff circuit is triggered. Now the trigger from the pickoff circuit (signal E) is fed to the A sweep generator. The A sweep generator is triggered and produces a sawtooth sweep voltage (not shown in fig. 61) and an unblanking pulse (signal F, fig. 61). The indicator circuits combine the A and B sweep unblanking pulses (signal G, fig. 61). This combining of the unblanking pulses results in an increase in CRT current, thus intensifying the trace for a period equal to the unblanking pulse time of sweep A (pattern H of fig. 61).

14-30. Look again at the A sweep unblanking pulse in figure 61 (signal F). Note that it lasts for 50 μsec. If the TIME PER CENTIMETER control is set to 5 μsec per centimeter as previously stated, then the A sweep generator produces a sawtooth of the same amplitude as the B sweep sawtooth but in a shorter time.

- A sweep time = 5 μsec/cm × 10 cm = 50 μsec.
- B sweep time = 20 μsec/cm × 10 cm = 200 μsec.

In this application the A sweep sawtooth is not used, but its unblanking pulse is used. This pulse is equal in duration to the A sweep sawtooth, so its duration must also equal 50 μsec. The indicator sweep is the result of the much slower B sweep signal, so the 50-μsec A sweep unblanking pulse intensifies the B sweep for only 2 1/2 centimeters (50 μsec 20 μsec-per centimeter = 2 1/2 cm).

14-31. Now let's summarize what we know about the "B" INTENSIFIED BY "A" function.

- The B sweep is triggered and functions just like the A sweep.

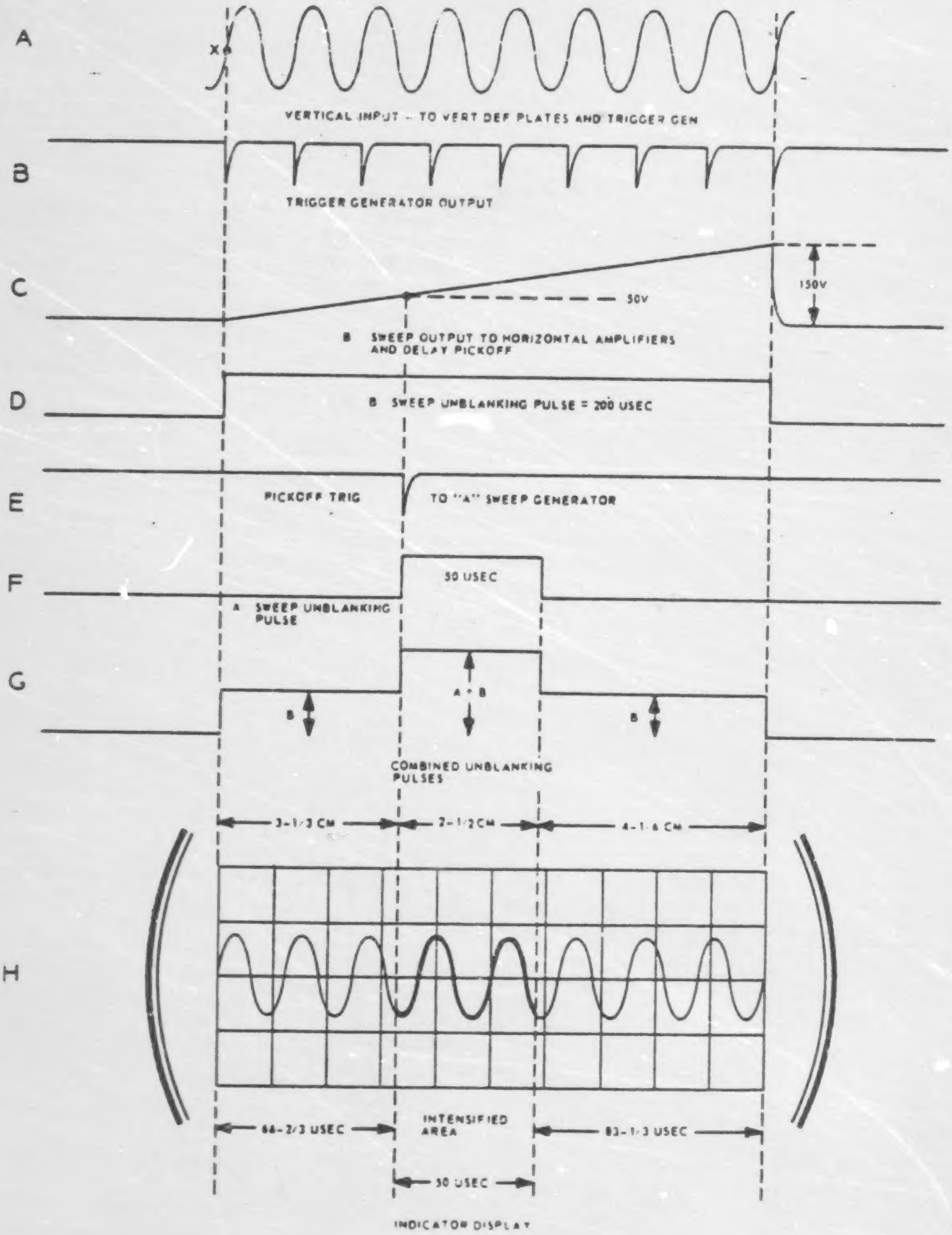

A
X
VERTICAL INPUT – TO VERT DEF PLATES AND TRIGGER GEN
B
TRIGGER GENERATOR OUTPUT
C
50V
150V
B SWEEP OUTPUT TO HORIZONTAL AMPLIFIERS AND DELAY PICKOFF
D
B SWEEP UNBLANKING PULSE = 200 USEC
E
PICKOFF TRIG
TO "A" SWEEP GENERATOR
F
50 USEC
A SWEEP UNBLANKING PULSE
G
B
A + B
B
COMBINED UNBLANKING PULSES
3-1/3 CM
2-1/2 CM
4-1/6 CM
H
66-2/3 USEC
INTENSIFIED AREA
83-1/3 USEC
50 USEC
INDICATOR DISPLAY

Figure 61. Intensified sweep

- The B sweep sawtooth voltage is fed to a pickoff circuit that produces a trigger for the A sweep generator at a time determined by the DELAY-TIME MULTIPLIER control.
- The A sweep unblanking pulse intensifies a portion of the B sweep.
- You can select the portion of the B sweep that you wish to intensify by varying the setting of the DELAY-TIME MULTIPLIER control.

14-32. There are times when you may wish to use this intensification principle to determine the frequency of the signal being displayed, the period or pulse width of the signal, or the signal rise time. To do this, reduce the setting of the A sweep TIME PER CENTIMETER control until the A sweep unblanking pulse is so short that the intensified portion of the trace appears as a small intensified dot.

14-33. Now look at figure 62. This figure shows three examples of how the intensified dot can be used. In figure 62,A, you can determine the frequency of the displayed signal in the following manner:

- First, place the dot at point X by setting the DELAY-TIME MULTIPLIER control to zero centimeters.
- Now turn the MULTIPLIER control until the dot moves to point Y, a distance that represents one cycle, and record the control setting.
- Subtract setting X from setting Y (the result in this case should equal setting Y, since setting X is zero). Now multiply this difference by the setting of the "B" TIME PER CENTIMETER control to obtain the time per cycle. Convert the time per cycle to frequency by the formula $F = \frac{1}{t}$. This same procedure can be used to determine the pulse width in figure 62,B, or the time between pulses in figure 62,C. You may wonder why it is necessary to do this when you can simply count the number of centimeters directly off the face of the indicator. This can be done, but not with the accuracy obtained by using the micrometer type DELAY-TIME MULTIPLIER control. These are only a few examples of how the intensified sweep can be used; however, in your day-to-day performance of maintenance, I am sure you will find many other useful applications.

14-34. You will find it convenient at times to be able to obtain an expanded view of one particular part of a display. This is probably the most important application of the intensified sweep. This can be done by intensifying the area you wish to expand and switching the HORIZONTAL DISPLAY control (fig. 54) to the "A" DELAYED BY "B" position.

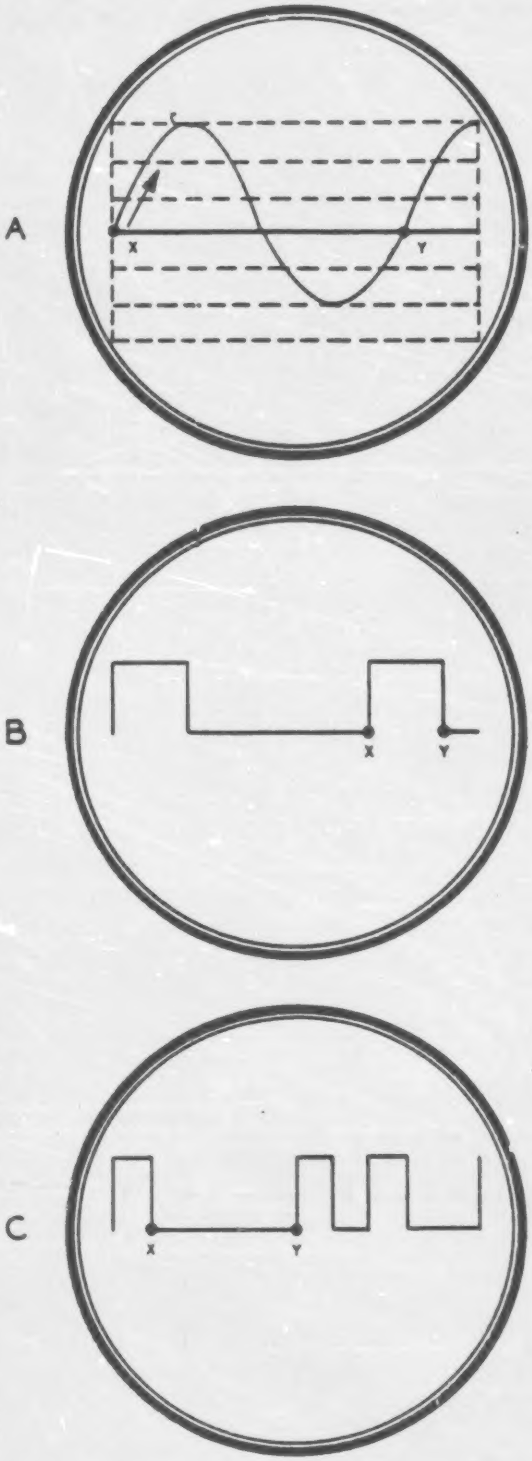


Figure 62. Measuring time with the intensity dot.

14-35. *"A" delayed by "B."* This sweep function is relatively simple. The only difference between it and the "B" INTENSIFIED BY "A" is that the indicator receives only the A sweep unblanking pulse and the A sweep sawtooth. The B sweep circuits are triggered just as they were in the "B" INTENSIFIED BY "A"; however, the B sweep outputs are not used by the indicator. The B sweep sawtooth triggers the pickoff circuit, which in turn triggers the A sweep. This happens at a time when the part of the input signal to be intensified is present at the vertical plates. The A sweep sawtooth and A sweep unblanking pulses are coupled to the indicator circuits and allow the intensified area to be displayed over the entire 10 cm.

14-36. Figure 63 shows more clearly what happens. The intensified sweep shown in figure 63,F, is obtained while the HORIZONTAL DISPLAY switch is in the "B" INTENSIFIED BY "A" position. The HORIZONTAL DISPLAY switch is then switched to the "A" DELAYED BY "B" position. The very next trigger received results in the generation of a B sweep sawtooth (fig. 63,B) and a B sweep unblanking pulse (fig. 63,C). The B unblanking pulse is not used. However, the B sweep sawtooth is fed to the pickoff circuit and when it rises to the pickoff point (fig. 63, B), the A sweep is triggered. The A sweep sawtooth (fig. 63,D) and the A sweep unblanking pulse (fig. 63,E) are coupled to the indicator. Thus, the intensified area between X and Y of figure 63,F, is displayed across the entire face of the indicator, as shown in figure 63,G.

14-37. The intensity-modulation principle can also be used to compare parts of a serial pulse train. Look at the display in figure 64,A. If you want to compare pulse A and pulse B, the best way is to superimpose one upon the other. Let's see what steps are necessary to do this with the oscilloscope shown in figure 54.

- Set the HORIZONTAL DISPLAY switch to the "B" INTENSIFIED BY "A" position and adjust the "A" TIME/CM and the DELAY-

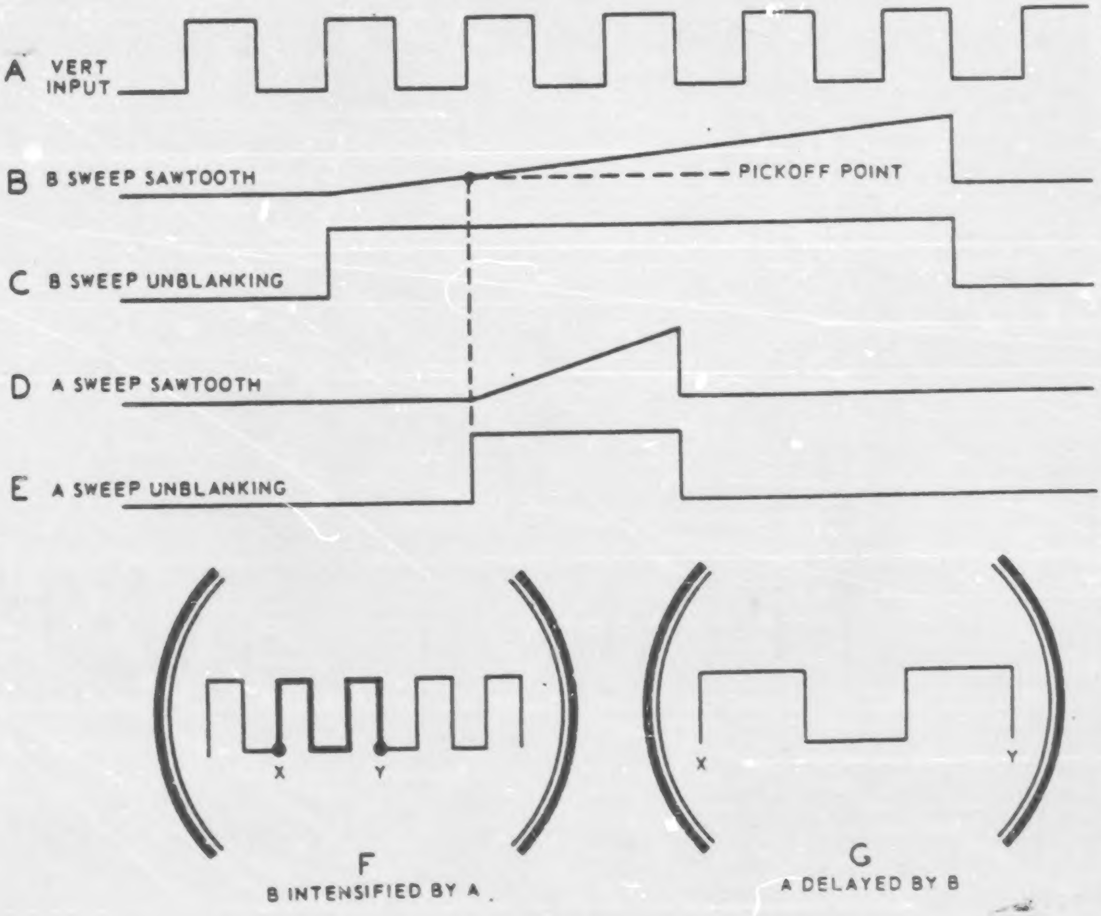


Figure 63. Display expansion

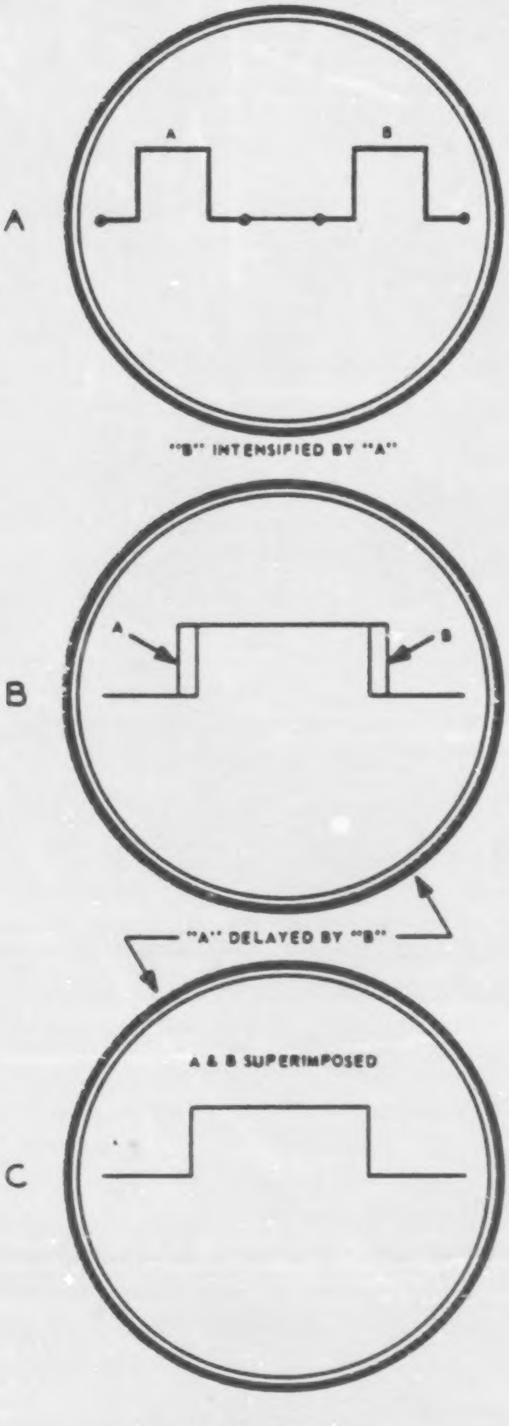


Figure 64 Pulse comparison

TIME MULTIPLIER controls until pulse B is intensified.

- Connect a small capacitor (approximately 100 $\mu\mu$f) between the B sweep unblanking pulse (fig. 54, +GATE B jack) and the pickoff trigger output jack (fig. 54, DLY'D TRIG jack).

14-38. When the B sweep unblanking pulse starts, it is coupled via the DLY'D TRIG jack to the A sweep generator. The A sweep generator is triggered and its unblanking pulse intensifies the pulse A area on the indicator. The pickoff circuit was already set to trigger the A sweep, so the pulse B area is intensifed. Now think about what is happening. Each B sweep triggers the A sweep twice, once at the beginning of the sweep and once at the pickoff point. Now switch the HORIZONTAL DISPLAY switch to the "A" DLY'D BY "B" position. The first time the A sweep is triggered it displays pulse A, and the second time it is triggered, it displays pulse B. This display is shown in figure 64,B, with the two pulses not quite matched. A slight adjustment of the DELAY-TIME MULTIPLIER control will move pulse B from where it is shown in figure 64,B, and position it directly over pulse A as shown in figure 64,C.

14-39. The oscilloscope shown in figure 54 is capable of two other sweep applications that are not a function of the dual-sweep generator principle, so let's take a look at them.

14-40. *"A" single sweep.* Look again at figure 54 and note the HORIZONTAL DISPLAY switch position that is labeled "A" SINGLE SWEEP; also observe the RESET button above and to the right of the display switch. With the switch in this position, a single sweep (one time across the scope) is obtained each time the RESET button is depressed. Your eyes and mind can obtain very little knowledge from seeing a signal for so short a time; however, with a camera and high-speed film a picture can be taken of this single trace. This picture then becomes a permanent record of the function displayed and the function can be analyzed at your leisure.

14-41. *External sweep.* Most oscilloscopes have provisions for the direct application of an external signal to the horizontal amplifiers. The EXTERNAL SWEEP function is especially applicable if you are to compare the phases of two sine waves. One signal is applied to the vertical input and the other signal is applied to the horizontal circuits via the HORIZONTAL INPUT jack (fig. 54, just to the right of the HORIZONTAL DISPLAY switch). With the HORIZONTAL DISPLAY switch in the X1 position, the horizontal input signal is fed directly to the horizontal amplifiers. In the X10 position, the horizontal input signal is attenuated by a factor of 10 before application to the horizontal amplifiers. Figure 65,A,

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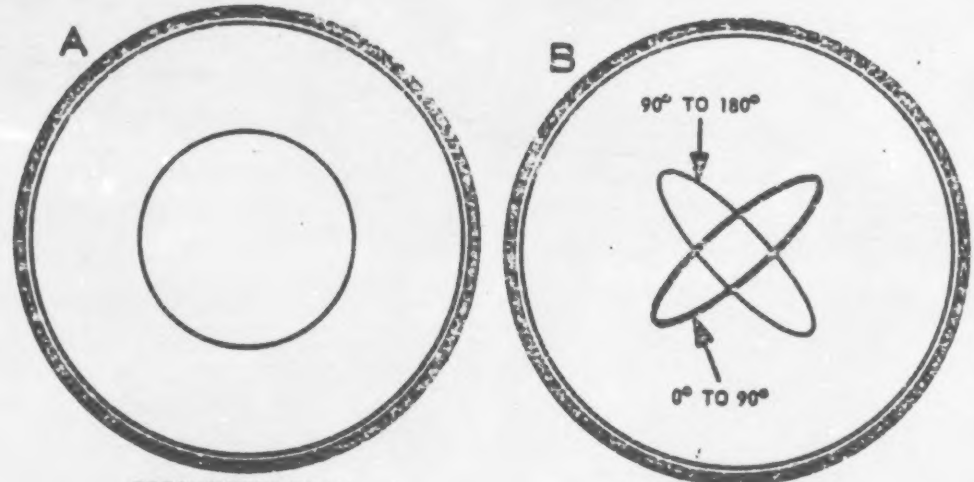
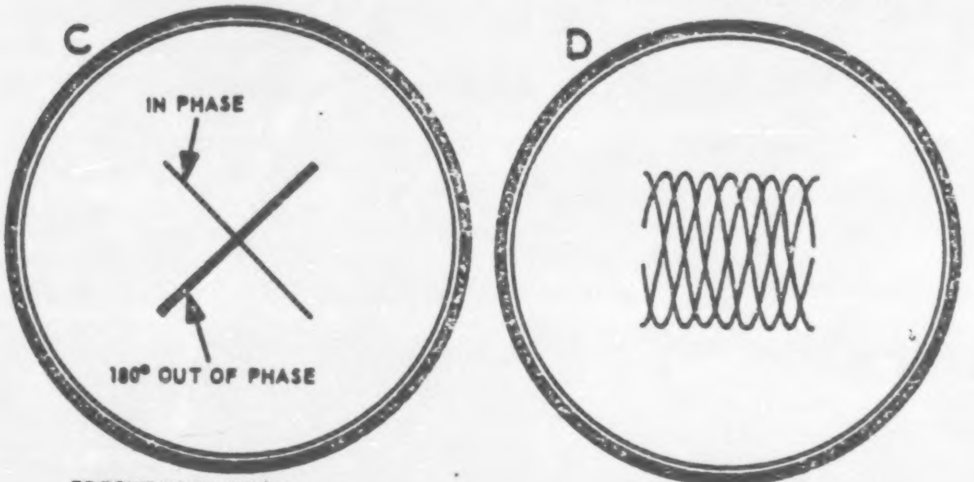


FREQUENCIES EQUAL
90° OUT OF PHASE

FREQUENCIES EQUAL
PHASE RELATION
0° TO 90° OR 90° TO 180°



FREQUENCIES EQUAL
IN PHASE OR 180° OUT OF PHASE

FREQUENCIES
NOT EQUAL

Figure 65. Lissajous patterns.

shows the display obtained when applying two sine waves of equal frequency but 90° out of phase. This pattern and the other patterns of figure 65 are based on equal horizontal and vertical deflections (the vertical input attenuator must be adjusted to make the vertical deflection equal to the horizontal deflection). An oval pattern such as shown in figure 65,B, is obtained when the phase difference is between 0° and 90° or between 90° and 180°. A single line presentation as shown in figure 65,C, is obtained when the signals are in phase or 180° out of phase. Figure 65,D, is the display obtained when the horizontal and vertical input signals are not of the same frequency. These are the basic Lissajous patterns which you learned in basic electronics, and they may be used to measure unknown frequencies when you have a known standard, or to calculate phase differences in known signals.

14-42. **The Plug-In Unit.** The oscilloscope, like many other pieces of test equipment, uses various plug-in units to increase its versatility. The oscilloscope shown in figure 54 has a type 82, dual-trace plug-in unit installed. This plug-in unit is just one of many that can be installed in the oscilloscope. All of these plug-in units provide preamplification and/or attenuation of the vertical input signal. Other functions performed by the various plug-in units follow:

- Vertical positioning of the display.
- Acceptance of two vertical input signals.

- Display of either of two vertical input signals separately.
- Alternate display of two vertical input signals on separate baselines.
- Chopped display of two input signals alternately selected and displayed on separate baselines while the sweep is in progress.
- Display of the algebraic sum of two vertical input signals.

14-43. Your choice of the plug-in unit you wish to use depends on the frequency response necessary, pulse characteristics, and the type of display that provides the most convenient analysis of the signal. You will learn of many needs through practical experience. To aid you in making the proper choice, let's discuss the use of plug-in unit controls to obtain the functions listed above.

14-44. *Vertical positioning.* All plug-in units have front panel vertical positioning controls. This control references the input signal so that it can be moved vertically on the indicator. The input signal is applied to a paraphase amplifier, which produces two outputs that are 180° out of phase. These two signals are amplified, and each is applied to a vertical plate. One signal is applied to the upper deflection plate, and the other to the lower deflection plate to produce a push-pull vertical deflection. The VERTICAL POSITION control varies the DC reference level that these two signals ride and thus positions the signal in the vertical plane.

14-45. *The input selector.* The input signal is applied to the INPUT jack either directly or via an attenuator probe. In the AC position of the INPUT selector switch (see fig. 54), a capacitor is placed in series with the input signal. This capacitor eliminates any DC component of the input signal. If you wish to check DC levels or DC reference levels of AC signals, place the INPUT selector switch in the DC position. In this position the signal is directly coupled to the vertical preamplifier.

14-46. *The input attenuator.* All vertical input signals are applied to an input attenuator network. The amount of attenuation is a function of the VOLTS/CM control (see fig. 54). The positions of this control indicate the amplitude of the input voltage necessary to deflect the beam 1 centimeter vertically; thus, if the switch is in the 5-volt position, an input signal will deflect the beam 1 centimeter for every 5 volts amplitude. Look at the VOLTS/CM control and the display shown in figure 66. The signal displayed occupies 3.5 cm vertically, and the VOLTS/CM control is set at the 0.5-volt position. You can calculate its peak-to-peak voltage amplitude as follows:

Volts/cm × cm of deflection = amplitude (peak to peak)
0.5 × 3.5 = 1.75 volts

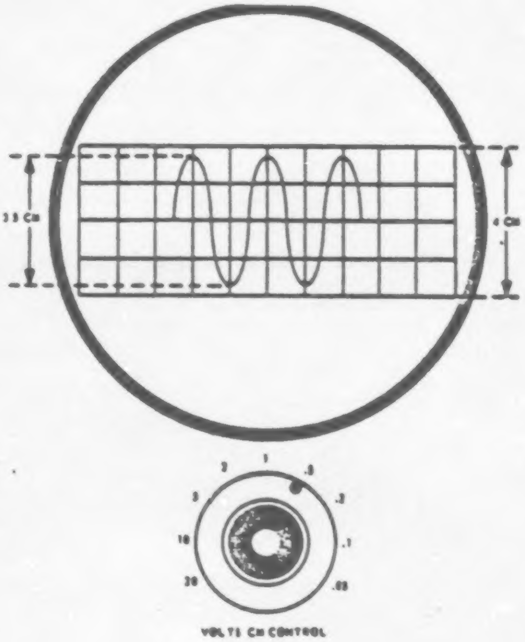


Figure 66. Measuring amplitude.

14-47. To measure the amplitude of a DC signal, you first set the sweep baseline to some logical reference level before applying the signal. You use the VERTICAL control to do this. Now when you apply the signal, you need only to determine the distance in centimeters that the baseline has moved and multiply this figure by the setting of the VOLTS/CM control. An example of a DC voltage measurement is shown in figure 67. Note where the baseline was set prior to the application of the input signal. If you count the number of centimeters, you can see that the input signal moved the baseline 2 1/4 centimeters. The VOLTS/CM control in the figure is set to the 5-volt position; therefore, the amplitude of the DC input equals 11.25 volts (5 × 2 1/4 = 11.25).

14-48. You may at times be required to determine the DC reference level of an AC signal. To do this, place the INPUT selector switch in the AC position. With the VERTICAL POSITION control, set the signal to some reference level. Place the INPUT selector to the DC position and determine the number of centimeters that the reference level shifted. In figure 68,A, the signal is shown set to a zero reference level with the INPUT

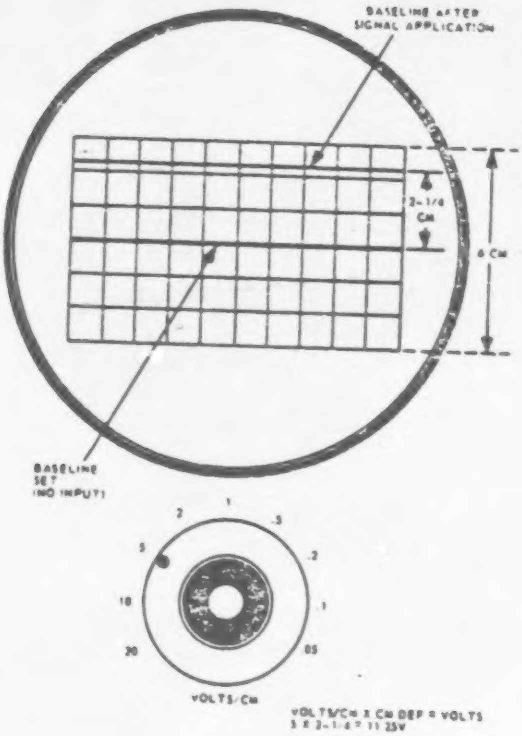


Figure 67. Measuring DC voltages.

selector in the AC position. Figure 68,B, shows that the reference level shifted 1 centimeter when the INPUT selector was set to the DC position. The DC reference voltage of this signal can be determined by multiplying the setting of the VOLTS/CM control by 1 centimeter. If the VOLTS/CM control was set to its 20-volt position in the example of figure 68, the DC reference level would be: 1 cm × 20 volts/cm = 20 volts.

14-49. *Dual trace.* The principles discussed thus far apply to all types of preamplifiers. In dual-trace preamplifiers (the one shown in figure 54) these functions are duplicated, and in addition there is an input attenuator and a vertical control for both the A and B sections of the preamplifier. In addition to dual controls, the dual-trace plug-in unit has two vertical input jacks and a switching multivibrator. The switching multivibrator and its associated circuits are used to alternately select one of the two vertical inputs on a time-sharing basis for application to the vertical amplifiers.

14-50. If you wish to compare two signals for phase, amplitude, shape, or any other reason, connect one input to the B section and the other input to the A section (see fig. 54).

For a two-sweep comparison you perform the following setup procedure:

- Place the MODE switch (see fig. 54) in the "A" ONLY position and adjust the A vertical positioning and the A attenuator controls until the presentation occupies the upper half of the display area (see fig. 69,A).
- Place the MODE switch in the "B" ONLY position and adjust the B vertical positioning and B attenuator controls until the B input occupies the lower half of the display area (see fig. 69,B).
- Place the MODE switch in the ALTER (alternate) position and the dual-sweep display is as shown in figure 69,C.

14-51. With this setup, the A vertical input signal triggers the sweep circuits, is coupled to the vertical plates, and is displayed. When the first sweep is completed, the switching multivibrator is then used to select the B vertical input. The next sweep displays the B vertical input signal. This switching action is repeated at the end of each sweep. If you wish to use this type of display to check the phase relationship of two signals, use an external trigger source of known relationship to the signals under test. Internal triggering should not be used because each signal would trigger its own sweep and the phase relationship could not be checked.

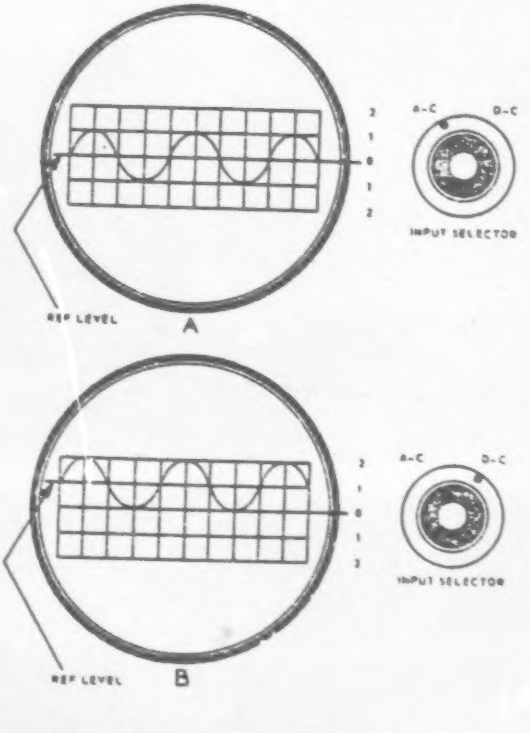


Figure 68. Measuring DC reference levels.

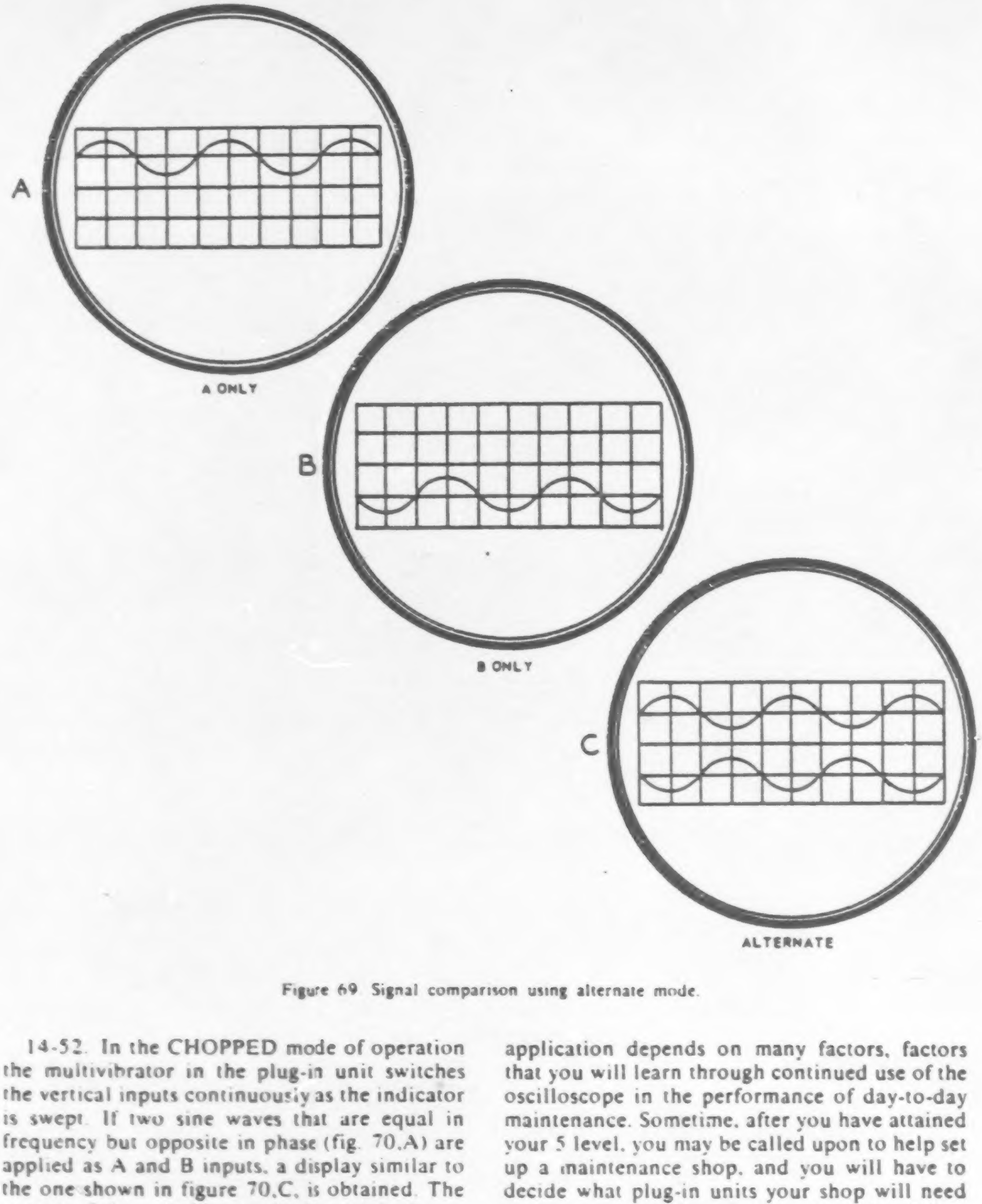


Figure 69 Signal comparison using alternate mode.

14-52. In the CHOPPED mode of operation the multivibrator in the plug-in unit switches the vertical inputs continuously as the indicator is swept. If two sine waves that are equal in frequency but opposite in phase (fig. 70,A) are applied as A and B inputs, a display similar to the one shown in figure 70,C, is obtained. The output of the switching multivibrator is shown in figure 70,B. The A input is displayed each time the output of the multivibrator is at its high level, and the B input signal is displayed each time the output of the multivibrator is at its lower level. The resultant display is shown in figure 70,C.

14-53. We have stated previously that the choice of plug-in units for a particular application depends on many factors, factors that you will learn through continued use of the oscilloscope in the performance of day-to-day maintenance. Sometime, after you have attained your 5 level, you may be called upon to help set up a maintenance shop, and you will have to decide what plug-in units your shop will need to best accomplish the assigned tasks. When this happens, you will have to apply principles learned in this CDC plus knowledge acquired on the job in making the selection. Before leaving the oscilloscope and going on to other test sets, let's discuss built-in calibration and indicator control circuits.

14-54. **Calibration.** In the performance of your job there are many times when you must measure signal levels and signal excursions. In displaying signals to see if they meet proper specifications, it is necessary to know that your scope is properly calibrated. There are two calibration check procedures that you must perform frequently. These are:

- Volts per centimeter.
- Attenuator probe.

14-55. To perform these checks, you need a standard that provides a square wave of known amplitude. In the case of the oscilloscope shown in figure 54, such a source is provided as a built-in feature. This circuit is called the *amplitude calibrator*. Its control and output jack are located in the lower right corner of the front panel (see fig. 54). The various positions on the amplitude calibrator control provide, at the CAL OUT jack, a square-wave signal ranging from 0.2 millivolt peak to peak to 100 volts peak to peak. This output is applied as a vertical input to determine whether the VOLTS/CM control is accurately calibrated. After you have checked the VOLTS/CM control and found it to be accurate, the attenuator probes are placed between the CAL OUT jack and the VERT INPUT jack to determine their accuracy.

14-56. When checking the attenuator probes, it is also necessary to check them to see if they cause any differentiation or integration of the input signal. If, when the CAL OUT is connected directly to the vertical input, a perfect square wave is presented on the oscilloscope indicator, but distortion is noted

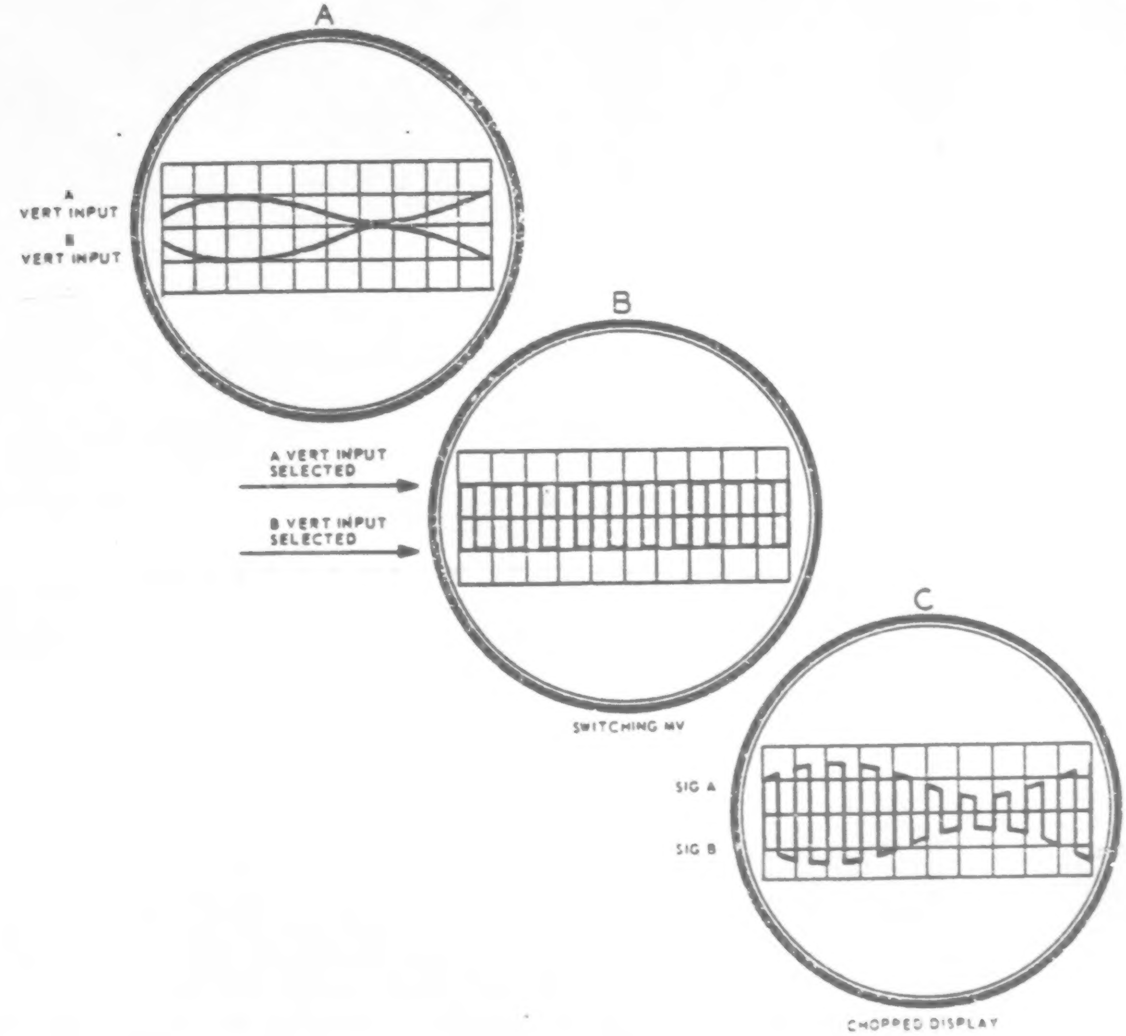


Figure 70. Chopped mode.

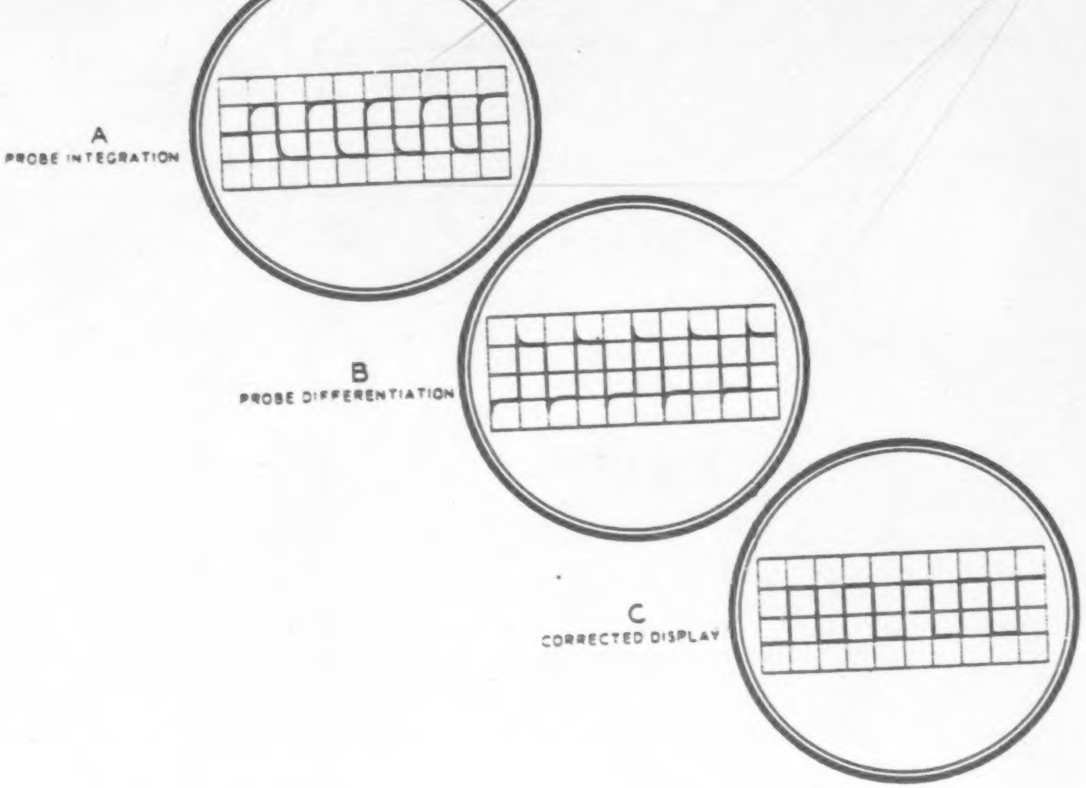


Figure 71. Adjusting the attenuator probe.

with the probe in the line, then an adjustment of the probe is necessary. Two common types of probe distortion are shown in figure 71, A and B. The distortion shown in figure 71,A, is due to integration, and that shown in figure 71,B, is due to differentiation. Probe distortion can usually be eliminated by adjusting the capacitor within the probe until the display appears as shown in figure 71,C. There is no set schedule for performing these calibrations, but you will find it good practice to check your scope in this manner before each use of the probes.

14-57. **Indicator Controls.** There are four front panel controls associated with the indicator of the oscilloscope shown in figure 54. The SCALE ILLUM controls the intensity of a light that illuminates the centimeter markings on the etched scale in front of the indicator face. The FOCUS and ASTIGMATISM controls are used together to obtain a clearly defined horizontal trace across the face of the indicator. The INTENSITY control sets trace brightness by varying the emission of the indicator cathode. Once set, the SCALE ILLUM, the FOCUS, and the ASTIGMATISM controls will usually need no readjustment; however, the INTENSITY control may need resetting for each new signal measured. This is due to the fact that the illumination of the trace is a function of both the strength of the electron beam and the frequency of the sweep. It may also be necessary to adjust the intensity when you wish to look at the leading and trailing edges of pulses that have very short rise and fall times. It is good practice to turn the intensity down when you leave your oscilloscope for extended periods, because a high-intensity beam will burn the coating on the indicator face.

15. Probes

15-1. In this section we discuss probes which are commonly used to extend the capabilities of meters and oscilloscopes. Two important types of probes are high-voltage and isolation probes. Their construction, purpose, and use should be clearly understood since they are necessary accessories for many kinds of measurement.

15-2. **High-Voltage Probes.** Test

instruments usually have a voltage measuring range that extends up to a maximum of 2000 volts. Relatively few have ranges that extend up to 6000 volts. When it is necessary to measure voltages that exceed the maximum rated voltage of your test instrument, you must extend the voltage range to a higher value. There are two ways to do this: (1) Connect an external multiplier resistor of suitable value in series with the input circuit of the test instrument or (2) use a capacitive divider circuit. We show how each of these ways is used in probes designed for high-voltage measurements.

15-3. The multiplier resistors normally used with 20,000 ohms/volt VOMs and VTVMs are generally of the high-voltage cartridge type, using a spiral film-type resistive element printed on a ceramic core, as illustrated in figure 72. The probe body housing for the removable multiplier resistor is composed of an insulating material having a high dielectric strength and a low leakage factor. Safety flanges are normally placed on the probe body to minimize surface leakage and corona and to protect the operator's hand from high-voltage shock or RF burns. The probe tip may be pointed for making probe contact, or it may be of the clip-on type for a more permanent connection. An insulated handle is provided for protection from electrical shock. A shielded cable is normally used from the probe to the meter to eliminate stray field pickup. An internal shield, grounded to the external cable shield, is used to ground accumulated electrostatic charges and thus minimize the possibility of RF flashover voltages.

15-4. Figure 73 shows a resistor probe connected to a volt-ohm-milliammeter (VOM). You must bear in mind that the input resistance of the VOM is changed for each setting of the DC voltage range switch. Therefore, the calculated value of the multiplier resistor required to obtain a given multiplying factor is valid only for the particular range switch setting that was used in the original calculation. By contrast, the value of the multiplier resistor need be calculated only once for all meter range settings if a VTVM is used. As shown in figure 74, the range switch of a VTVM selects a definite proportion of the input voltage for application to the voltmeter bridge circuit. But since the VTVM tube draws no current from the input circuit, the resistance of the voltage divider located in the input circuit is constant for all ranges. Thus, the probe multiplies each range of the VTVM by the same factor. Therefore, the same resistor may be used with all range scales. This is not true, however, for VTVM models having different values of internal voltage divider resistance.

15-5. The internal resistor contained in the probe body also provides circuit isolation. This resistor, usually having a value of 1 megohm, performs a double function: (1) it reduces the capacitance which the probe introduces to the circuit under test, and (2) it acts as the resistive element of an RC filter network to aid in the removal of high-frequency AC components from the output of the measured equipment.

15-6. For example, the combined total input capacitance of the VTVM, including the input cable of the probe and the test probe itself, is approximately 100 picofarads. This capacitance, if applied across the circuit under test as shown in figure 75, loads down and unbalances the RF circuits while you are

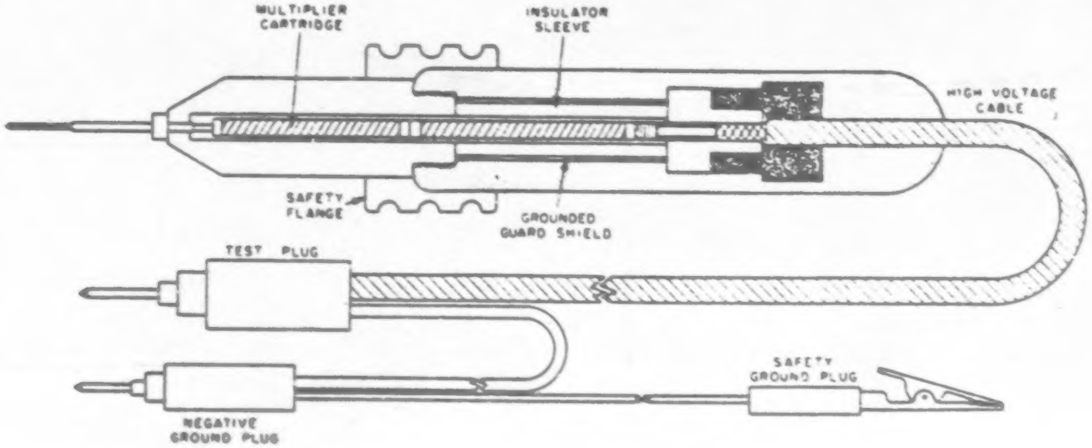


Figure 72. High-voltage DC probe.

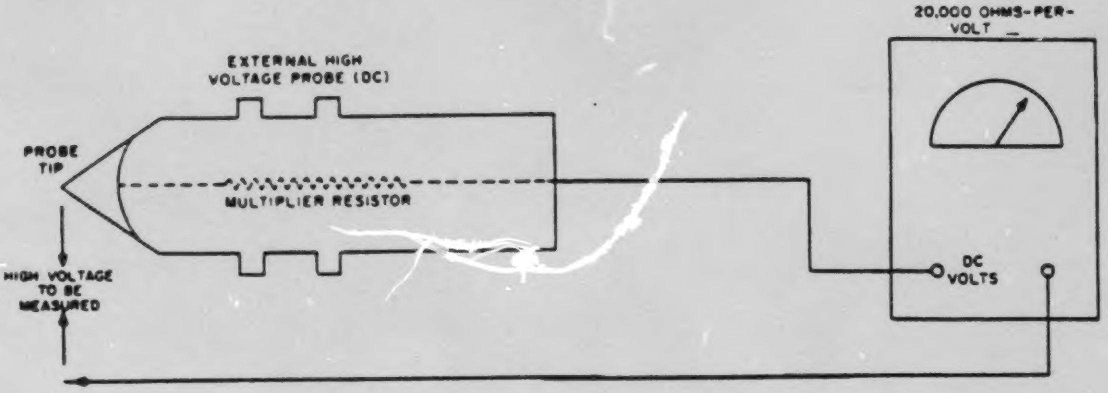


Figure 73. Probe connected to DC voltmeter.

measuring the associated DC voltages with the VTVM. Your DC measurements under these circumstances are both erroneous and misleading. Therefore, the isolation resistor contained in the probe used with a VTVM is necessary to remove or reduce these capacitive effects from the circuit being tested. A case in point would be the measurement of the DC grid bias of a high-frequency oscillator. Elimination of the cable shielding does not eliminate the capacitive effects because stray fields are then induced into the tested equipment through the unshielded cable. Therefore, you must insert a high-ohmage resistor between the circuit test point and the shielded cable from the VTVM input voltage divider circuit (see fig. 76). Although there still is some capacitance from the probe tip to ground, it is comparatively small. If the original reactance of the probe is in the neighborhood of 100,000 ohms for a particular test circuit frequency and you inject a series 1-megohm resistor into the circuit, the total impedance is greater than a megohm. This makes the reactive component only 10 percent rather than the original 100 percent of the total input impedance.

15-7. The resistor probe is also employed with an oscilloscope to measure peak-to-peak waveform values or simply to observe the general form of the measured waveform. Furthermore, the input terminals of most scopes are rated at 600 volts maximum; therefore, the probe is used to prevent the application of excessive voltage that may, at the very least, distort the reproduced waveform or, more seriously, puncture the input capacitor, damage or burn out the internal scope attenuator resistors, carbonize terminals strips by an arc-over process, or cause additional attendant damage by completely overloading the input scope amplifier. The isolating resistor in the probe and the internal resistance of the oscilloscope may be used as a form of voltage divider network for either DC or low-frequency measurements and, in some cases, provides a voltage reduction ratio as high as 1000:1. A 10,000-volt signal, in this instance, would cause an actual value of 10 volts to be applied

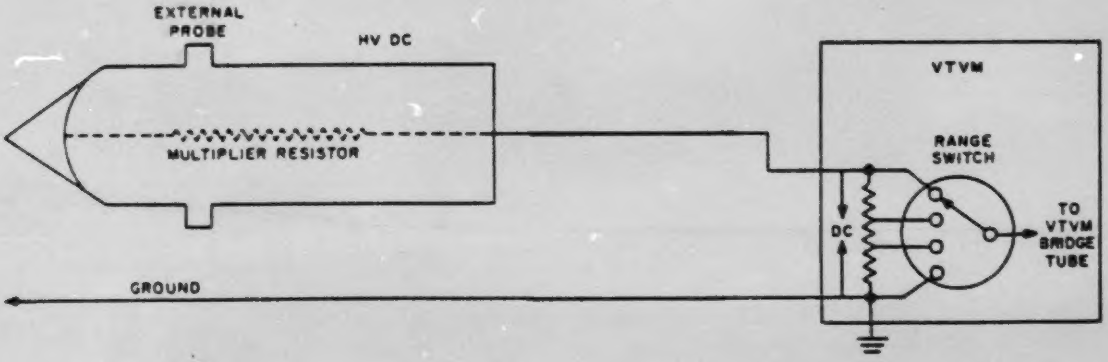


Figure 74. Probe connected to VTVM.

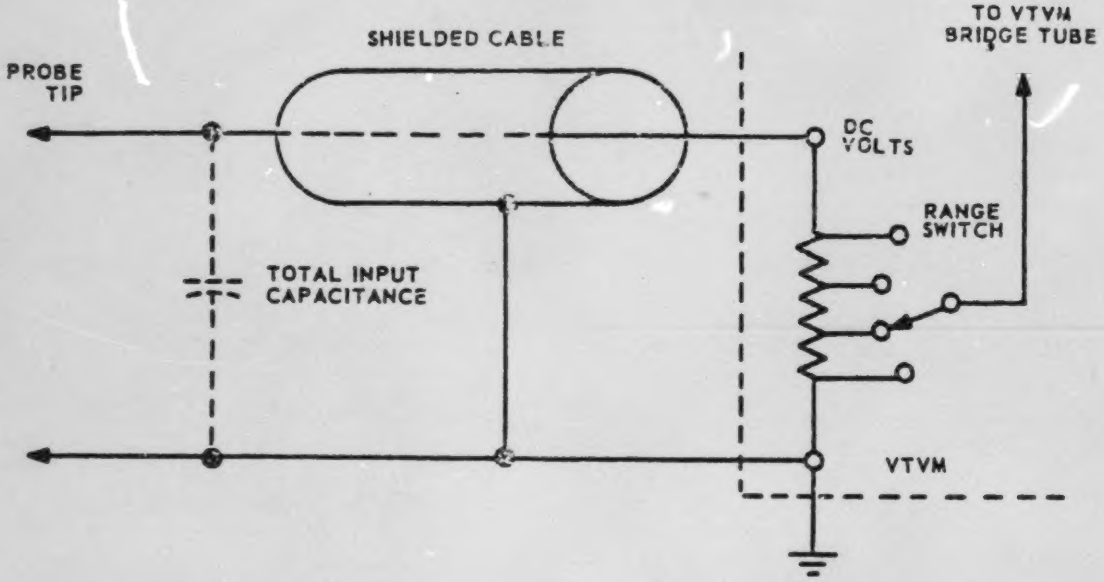

SHIELDED CABLE
TO VTVM BRIDGE TUBE
PROBE TIP
DC VOLTS
RANGE SWITCH
TOTAL INPUT CAPACITANCE
VTVM

Figure 75. Effective input capacitance.

to the vertical input terminals of the scope. Unfortunately, some oscilloscopes do not provide an internal resistance network across the vertical terminals; therefore, you may have to construct a voltage divider network to protect the scope input circuits.

15-8. By simply connecting a large ohmage resistor, such as 1 megohm, across the vertical input terminals of the scope, the required voltage division can be obtained. However, this type of resistive voltage divider has limitations which may preclude its use. The AC voltage division is not accurate at the higher frequencies because the amount of capacitance present between the probe body and ground changes with each new probe position. In addition, stray fields in the vicinity of the unshielded parts of your probe produce undesirable currents which distort the observed waveforms. Therefore, if this be the case, you cannot use this method to measure the exact amplitude and waveshape of a signal.

15-9. In the capacitive divider probe, the high voltage under test is applied across two capacitors connected in series. Figure 77,A, shows a diagram of the actual capacitive probe, and figure 77,B, illustrates the voltage dividing arrangement which protects the scope. The input voltage is divided across C1 and C2 of figure 77,B, in inverse proportion to their capacitive value. Normally, C1 is made much smaller than C2 so that most of the voltage will be dropped, or lost, across the capacitor. The remaining voltage, dropped across C2, is small

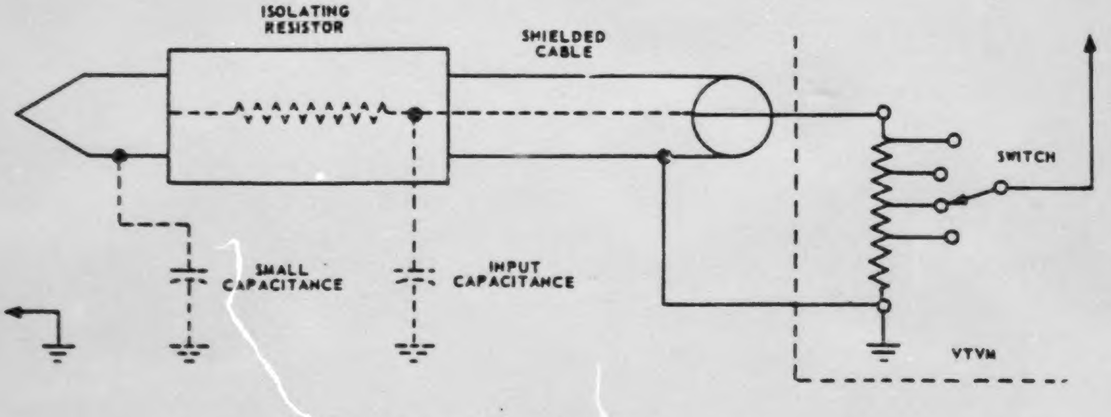

ISOLATING RESISTOR
SHIELDED CABLE
SWITCH
SMALL CAPACITANCE
INPUT CAPACITANCE
VTVM

Figure 76. DC probe with isolating resistor.

enough for safe application to the vertical scope terminals. The formulas required for the calculation of the capacitor values to provide the desired division of the applied high voltage are as follows:

$$E1 = \frac{E2C2}{C1} = E3 - E2$$

$$\frac{E3}{E2} - 1 = \frac{C2}{C1}$$

NOTE:

$$\frac{E3}{E2} = \text{stepdown ratio (R)}$$

$$C2 = C1\ (R - 1)$$

where: E1 is the voltage drop across C1, E2 is the voltage drop across C2, and E3 is the voltage applied to the divider network.

15-10. The high-voltage capacitance divider probe must contain an extremely high input impedance to prevent loading of the circuit under test. This high impedance is provided by using a high-voltage rectifier tube as an inexpensive capacitor with a breakdown voltage of up to 15,000 or 20,000 volts. The probe must have a body which provides high-voltage insulation features in its makeup, and the probe must be shielded to prevent stray field pickup which would distort the desired scope waveform. In figure 77,A, trimmer capacitor C2 and tube capacitance C1 form a voltage divider network. This trimmer capacitor, which is normally incorporated within the probe body, may be varied to provide the proper voltage ratio for application to the oscilloscope. The normal ratio is 100:1. Therefore, with an applied signal of 20,000 volts to the probe tip, only 200 volts appear across C2 and are delivered to the vertical terminals of the scope. In this case, the voltage breakdown rating of C2 need be only slightly higher than approximately 200 volts. Since the input and shielded cable capacitances, represented by C3 in figure 77,A, are in parallel with the trimmer capacitor located in the probe, C2 must be readjusted to the proper voltage stepdown ratio each time a different cable or scope is used with the probe.

15-11. If the stepdown voltage ratio is 100:1 and you measure 1000 volts, only 10 volts is applied to the scope. In this instance, you may calibrate the scope screen so that 1 volt is equal to 1 square; therefore, 10 volts approximate 10 vertical squares of height and represent 1000 volts of measured signal. The calibration procedure required to obtain a 10:1 or 100:1 voltage ratio is relatively simple. Many scopes do not contain a compensated input circuit, and therefore the oscilloscope trace varies in direct proportion to the input capacitance variation. This effect causes the probe calibration to change. Additional waveform distortion is apparent on such a scope because of frequency discrimination and phase-shift distortion. If the scope contains a compensated input, the following sequence of calibration applies:

a. Connect the vertical terminals of your scope directly across some low-impedance, low-voltage source, and set the scope step attenuator to its "times one" (× 1) position.

b. Vary the vernier attenuator for any convenient number of squares of screen deflection.

c. Connect the probe between the voltage source specified in step *a* above and the vertical scope terminals, and advance the scope step attenuator to its "times 100" scale (× 100). The waveform should now occupy the exact same number of scale divisions as it did previously.

d. If the number of squares occupied by the waveform are different from the number obtained in step *b* above, adjust the probe trimmer capacitor with an insulated

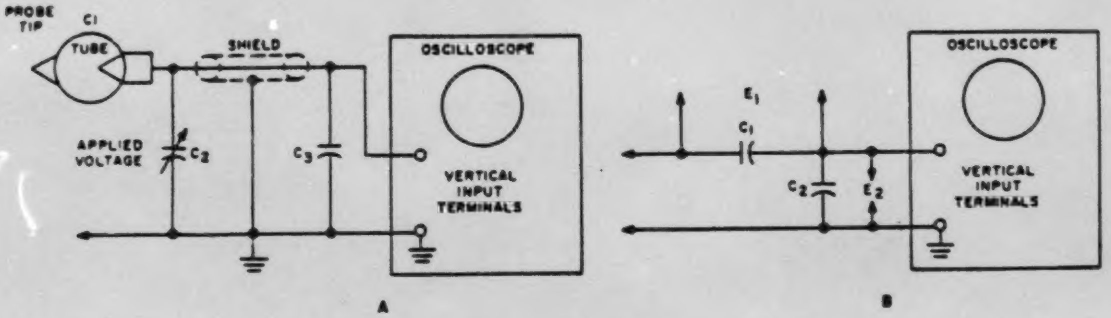


Figure 77. Capacitive voltage divider.

screwdriver until the waveform is the same. Now the scope is calibrated to receive 1/10 of any voltage applied to the probe tip, provided that you always use the same connecting cable and scope.

15-12. **Isolation Probes.** We have already spoken of the isolation feature of high-voltage probes, but more needs to be said about probes designed especially to provide isolation.

15-13. Across the vertical terminals of an oscilloscope there is normally a resistive element of from 0.1 to 2.0 megohms, in parallel with a small amount of capacitance. The capacitance is a combination of the capacitance normally present across the vertical terminals and the capacitance of the probe and its shielded cable. When such a scope is used in conjunction with a shielded cable and probe, it contributes from 0.1 to 2.0 megohms of resistance and from 40 to 90 picofarads of capacitance in shunt with the output of the circuit under test. If the circuit under test has a high output impedance or contains high-frequency components, this test equipment shunting effect detunes resonant circuits, loads other circuits, or simply distorts the desired waveforms. This undesirable condition is prevented or its effect decreased if you increase the impedance shunting the tested circuit. You can do this by using a low-capacitance high-impedance probe of proper design. Figure 78 illustrates the method of connecting a small variable capacitor in parallel with a large resistor within the probe head. This parallel combination is in series with the shielded cable and, consequently, is in series with the scope input. The scope-blocking capacitor is relatively large, so its reactance at high frequencies can be considered negligible. The small variable capacitor, C1, in series with the scope, cable, and probe capacitance, C2, decreases the total effective capacitance and thereby increases the capacitive reactance. The large value resistor, R1, acts as an isolating resistor, as discussed previously, and also effectively decreases the total input capacitance. These two parallel circuits, which are effectively connected in series, act as a voltage divider and, of course, decrease the amplitude of the AC signal being measured. Although this decrease in amplitude is wanted in a high-voltage probe, it is one of the unfortunate side effects of compensation and is termed *probe attenuation*.

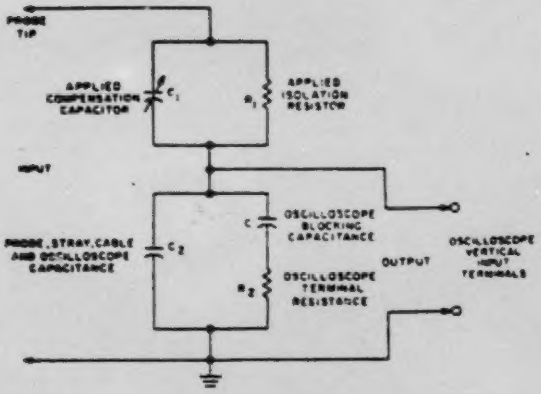

PROBE TIP
APPLIED COMPENSATION CAPACITOR
C_1
R_1
APPLIED ISOLATION RESISTOR
INPUT
C
OSCILLOSCOPE BLOCKING CAPACITANCE
PROBE, STRAY, CABLE AND OSCILLOSCOPE CAPACITANCE
C_2
OUTPUT
OSCILLOSCOPE VERTICAL INPUT TERMINALS
R_2
OSCILLOSCOPE TERMINAL RESISTANCE

Figure 78. Compensated low-capacitance isolation probe

15-14. The amount of probe attenuation must remain fairly constant during measurement at both low and high frequencies. Therefore, not only must the R1C1 provide a voltage ratio of 100:1, 10—1, or some other fraction, but R1C1 must be equal to R2C2 of the scope, probe, and cable. With these two time constants equal, the arrangement divides AC voltages at all frequencies by the same ratio, except when either resonance or antiresonance effects change the voltage delivered to the scope. (The latter effects occur so rarely that they may be neglected in most cases.)

15-15. Another way to provide isolation is to use a probe that is constructed by connecting an additional resistor, R, across the vertical scope terminals, as shown in figure 79. Thus, the isolating resistor and R comprise a resistive attenuation path for DC. This protects the scope blocking capacitor from DC voltage surges and, in addition, stabilizes the scope impedance as the vertical vernier control is varied. A probe of this design has one primary disadvantage; it may cause too much resistance loading on critical high-impedance DC circuits. Therefore, this type of probe is normally not used in such circuits unless a capacitor is inserted in series with the probe tip to block DC.

15-16. Yet another way to provide isolation is to use a cathode-follower probe. It has a cathode-follower circuit within the probe body to obtain a very high input and low output impedance characteristic. This type of probe has excellent high-frequency response and, since its input impedance is higher than its output impedance, it acts as an impedance transformer. Figure 80 illustrates the schematic diagram of the probe. The light circuit loading of this probe results from the use of a 6-megohm resistor shunted by approximately 10 picofarads of stray circuit capacitance. As shown, the 6-megohm resistor, the 0.05-microfarad coupling capacitor, and the 300-ohm cathode resistor are all in series and

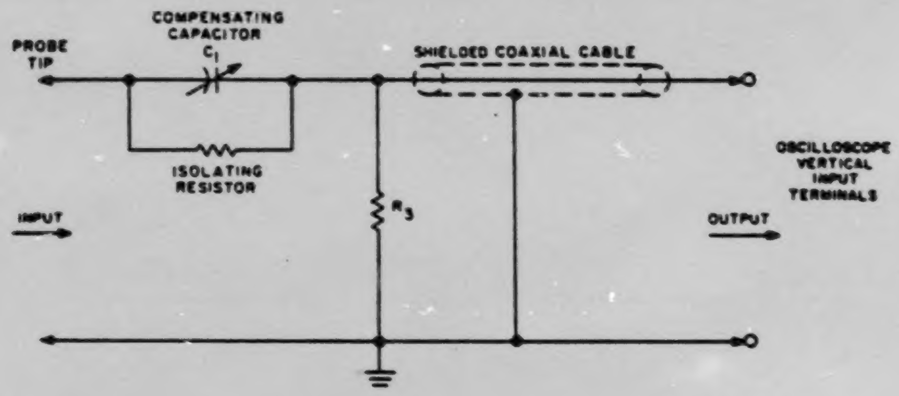

COMPENSATING CAPACITOR
C1
PROBE TIP
SHIELDED COAXIAL CABLE
ISOLATING RESISTOR
R3
INPUT
OUTPUT
OSCILLOSCOPE VERTICAL INPUT TERMINALS

Figure 79. Isolation probe with shunting resistor.

shunted across the output of the circuit under test. The output from the cathode follower is obtained across the 300-ohm cathode resistor which is in parallel with the high impedance of the scope (or other test instrument). Therefore, the scope input circuit does not load down the cathode-follower output.

15-17. **Shielding and Loading Effects of Probes.** As you may have surmised from the foregoing discussion, the test leads or cable that you use as the electrical link between a VOM, VTVM, or sctpe and the equipment under test becomes an integral part of the test instrument. You can use many different types of interconnections, such as two independent separated wires, two parallel wires in a cord arrangement, or a probe and shielded cable. The effect of the shunting input capacitance may be negligible in one circuit under test and may completely upset the normal operation of other circuits under test. In some cases, the use of unshielded test leads results in spurious pulse- or hum-voltage pickup, which distorts the signal applied to the VTVM or scope. This condition can exist because a magnetic field is produced around each wire having current flowing through it, and a potential between wires establishes an electrostatic field at right angles to the magnetic field. The magnetic field so produced represents a lumped value of inductance along the wires. The electrostatic field represents a lumped value of capacitance between the wires. Unfortunately, each time the leads are moved or shifted, the distance between them changes, and this changes the distributed capacitance between the wires or between the wires and nearby objects. At higher frequencies, the inductance and capacitance values may cause the tested circuit to actually oscillate and produce misleading meter indications. Also, the use of unshielded open-wire test leads and probes may have other adverse effects; for example, the test leads may act as an antenna and radiate a signal from an isolated or shielded circuit section to other circuit sections to cause circuit crosscoupling, regeneration, or oscillation. In addition, this stray field and adjacent circuit pickup or

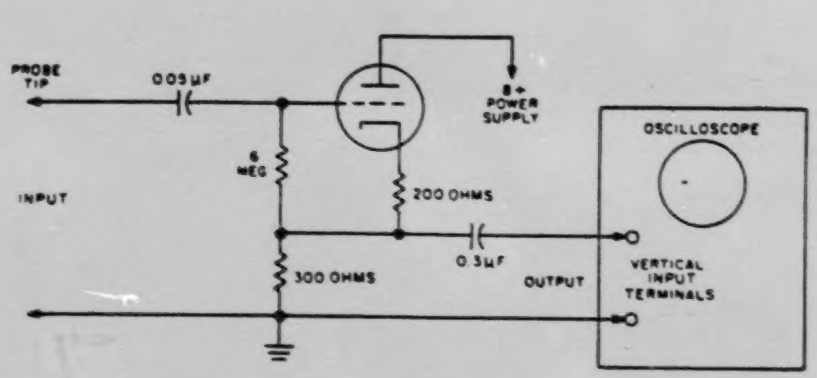

PROBE TIP
.005 µF
B+ POWER SUPPLY
OSCILLOSCOPE
6 MEG
INPUT
200 OHMS
0.5 µF
300 OHMS
OUTPUT
VERTICAL INPUT TERMINALS

Figure 80. Cathode-follower isolation probe

crosscoupling may be fed directly to your scope and be integrated with the desired scope trace to provide confusing or ambiguous results.

15-18. A shielded input cable does not always correct the difficulties encountered with twin-wire unshielded test leads. Both the shielded cable capacitance to ground and the VTVM or scope input capacitance may cause a loading effect on the circuit under test. In fact, errors in peak-to-peak signal measurement, as well as waveform distortion, may be evident. As we have explained previously, the use of an isolating resistor within your probe decreases the loading effect of your shielded cable and avoids the possibility of detuning high-frequency resonant circuits under test. In some areas of low-frequency measurement, however, the unshielded cable has less loading effect than the shielded test lead.

15-19. The use of a high-voltage 100:1 capacitance probe is a distinct advantage except when the output of the tested circuit is below about 5 or 10 volts. These low voltages will produce probe output signals less than 0.05 or 0.1 volt, which may not provide sufficient deflection for a good display.

15-20. The input impedance of a capacitor divider high-voltage probe is relatively high, but it becomes less as the frequency increases. At extremely high frequencies, the probe impedance becomes so low that this type probe cannot be used because of its loading effects.

15-21. When connecting test equipment to a circuit, you should always have some idea of the internal impedance of the circuit. This knowledge is necessary because the loading effect on the circuit is not determined solely by the shunt capacitance or inductance of the test equipment and leads. Since this shunt capacitance or inductance is in parallel with the internal impedance of the circuit under test (as shown in fig. 81), it is the relative values of the reactance and the internal impedance which determine whether or not the loading is appreciable. If Z is small compared to Xc, there is little or no effective loading. However, if Z is large in comparison, the loading is heavy enough to alter the operation of the tested circuit and distort the peak-to-peak signal or observed waveform. It is on the basis of this reasoning that we can say a given shunt impedance loads down a high-impedance circuit more heavily than it does a low-impedance circuit.

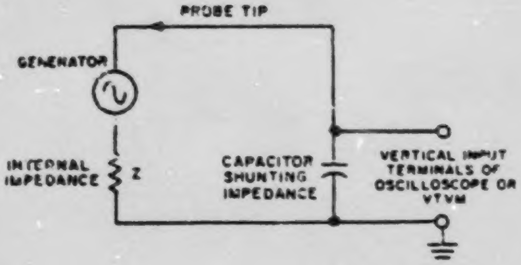

PROBE TIP
GENERATOR
INTERNAL IMPEDANCE
Z
CAPACITOR SHUNTING IMPEDANCE
VERTICAL INPUT TERMINALS OF OSCILLOSCOPE OR VTVM

Figure 81. Probe and cable loading.

15-22. Safety Precautions. As a safety precaution, the meter or scope ground terminal should be physically connected to the probe cable shield and to either the chassis or the B-line of the equipment being tested. If you do not ground the test instrument in this manner, it may be electrically hot and present a severe shock danger. When you test circuits containing no power transformer, you should remember to connect an isolation transformer between the equipment being tested and the line. This prevents you from shorting out the powerline if the meter case or chassis should become inadvertently or accidentally grounded. For maximum safety, the wearing of insulated shoes is advisable; if shoes which have exposed nail heads are worn, you should stand on a rubber mat or other insulated material. Keep one hand in your pocket at all times, and hold the probe by its handle with your other hand. Connect the probe tip to the equipment to be tested prior to the application of power. We have reviewed these precautions because you should bear them in mind whenever high voltages are measured.

15-23. At this time work the Chapter Review Exercises for Chapter 4 in your workbook.

Power and Frequency Test Equipment

IN ADDITION TO the test instruments already covered, there are many test instruments designed to test television, flight facilities, and radio equipments and many others designed for microwave measurements. In this chapter we will discuss the most important and commonly used in electronic test instruments that C-E repairmen need to perform their job. The instruments included are those that measure power and frequency. Signal generators will also be considered, since they are required for testing and troubleshooting.

16. Power Measuring Instruments

16-1. Electrodynamic wattmeters are widely used for the measurement of power. Other power-measuring instruments of importance are: output power meters, bolometer bridges, and calorimeters.

16-2. **Electrodynamic Wattmeters.** The *electrodynamic wattmeter* measures power taken from alternating-current or direct-current power sources. When measuring AC power, this instrument indicates the *in-phase* or real power. It can be modified, however, to indicate *reactive* power instead of *real* power. This instrument uses the reaction between the magnetic fields of two current-carrying coils (or sets of coils), one fixed and the other movable (see fig. 82). When the current through the fixed-position field winding(s) is the same as the current through the load, and the current through the moving coil is proportional to the load voltage, the instantaneous pointer rotation is proportional to the instantaneous power. Since the moving system cannot follow rapid variations in torque because of its longer natural period of vibration, its deflected position is where the average driving torque is equal to the restoring torque of the springs. Meter deflection is thus proportional to the average power.

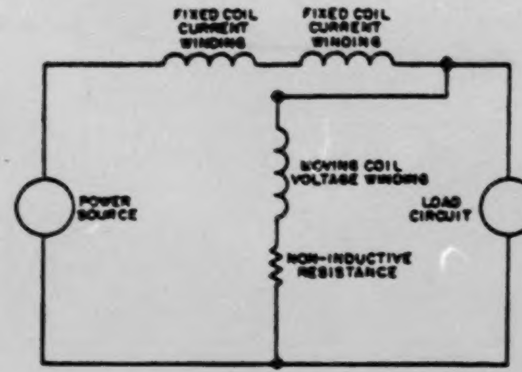

FIXED COIL CURRENT WINDING
FIXED COIL CURRENT WINDING
MOVING COIL VOLTAGE WINDING
POWER SOURCE
LOAD CIRCUIT
NON-INDUCTIVE RESISTANCE

Figure 82. Circuit of an electrodynamic wattmeter.

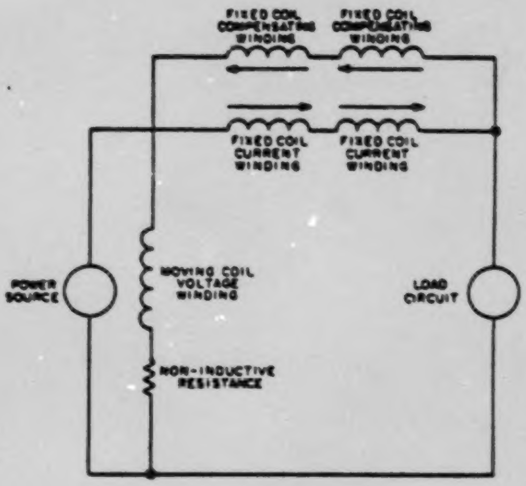

FIXED COIL COMPENSATING WINDING
FIXED COIL COMPENSATING WINDING
FIXED COIL CURRENT WINDING
FIXED COIL CURRENT WINDING
POWER SOURCE
MOVING COIL VOLTAGE WINDING
LOAD CIRCUIT
NON-INDUCTIVE RESISTANCE

Figure 83. A compensated wattmeter.

16-3. The dynamometer-type wattmeter automatically compensates for the power factor error of the circuit under test, since it indicates only the power resulting from *in-phase* components of current and voltage. With out-of-phase relationships, a current peak through the moving coil never occurs at the same instant as the voltage peak across the load. The result is less pointer deflection than when the current and voltage are in phase.

16-4. The simple meter shown in figure 82 indicates that power is being consumed after the load is disconnected. This difficulty can be eliminated by incorporating two compensating windings, mounted with the primary fixed-coil current windings, as shown in figure 83. These stationary windings produce a magnetic flux proportional to the current through the moving coil. As shown by the arrows in figure 83, the currents through the current windings and the compensating coils flow in opposite directions. Since these opposing fields cancel with the load removed from the circuit, the meter will indicate zero power.

16-5. Electrodynamic wattmeters are subject to errors arising from various factors, such as temperature and frequency characteristics of the moving system. Aside from heat dissipation in the various coils, heat through the control mechanism will cause the springs to lengthen and lose tension, producing deflection errors. Figure 84 illustrates the mechanical equivalent of the electrodynamic wattmeter. Large currents within the circuit will also produce appreciable error. Therefore, the maximum current range of electrodynamic wattmeters is normally restricted to about 20 amperes. When larger AC load currents are involved, a current transformer of suitable range is used in conjunction with the wattmeter. However, when measuring total power, a current transformer cannot be used if the AC circuit under test contains a DC component.

16-6. The voltage range of wattmeters is generally limited to several hundred volts because of heat dissipation within the voltage circuit. However, the voltage range can be extended by using external voltage multipliers.

16-7. Wattmeters used as laboratory standards have an accuracy of 0.1 percent, high-grade portable wattmeters have an accuracy of 0.2 to 0.25 percent, and high-grade switchboard wattmeters have an accuracy of 1 percent. Because electrodynamic wattmeter errors increase with frequency, the accuracy decreases appreciably for frequencies above 1000 hertz.

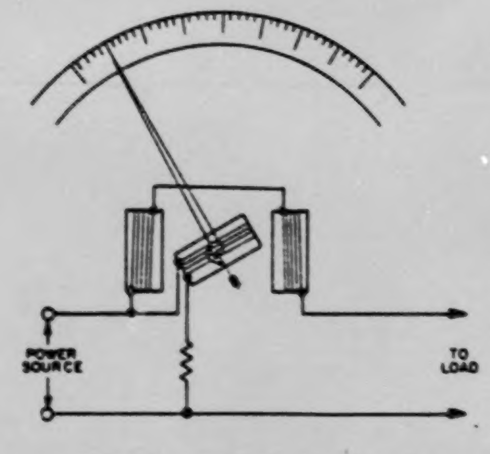


Figure 84. Mechanism of a wattmeter.

16-8. When using an unshielded electrodynamic wattmeter, you should not place it in the vicinity of stray magnetic fields. Also take care not to exceed the current, voltage, and power ratings of the wattmeter. Damage may result when any of these ratings is exceeded, although excessive meter deflection may occur only when the power rating is exceeded.

16-9. The electrodynamic wattmeter may be converted into an instrument for measuring reactive power by replacing the resistance, which is normally in series with the voltage coil, by a large inductance. A 90° current lag within the voltage coil provides a direct reading proportional to the reactive power in the circuit. Compensating networks must be used to cause the phase shift to be exactly 90°.

16-10. **Output Power Meters.** Unlike the electrodynamic wattmeter, the output power meter is restricted to the measurement of the dissipated power in a selective resistive load provided by the instrument inself. A diagram of a simple output power meter is shown in figure 85. The power is $\frac{E^2}{R}$ where E is the voltmeter reading. Since R is a fixed resistance of known value, the voltmeter can be calibrated to read directly in watts. By using different values of R or by providing various multiplier resistors in the voltmeter, it is possible for you to extend the range of the instrument. For the measurement of AC power, a tapped transformer can be used for extending the range (see fig. 86). The voltmeter is usually calibrated to read watts or decibels.

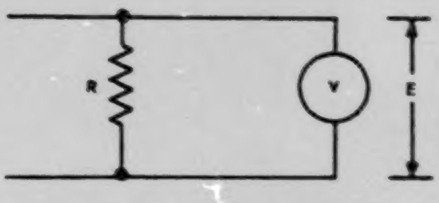


Figure 85. Basic output power meter circuit.

16-11. *Db meters.* A db meter is a rectifier type of AC voltmeter or an AC electronic voltmeter calibrated in db. The db meter can be incorporated as part of a volt-ohm-milliammeter, and the same jacks and switch

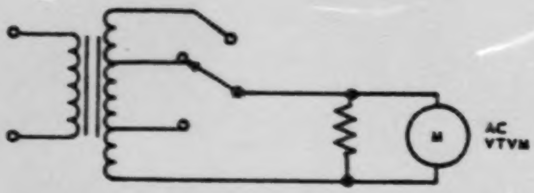


Figure 86. Tapped transformer for output power meter.

positions used for AC voltage measurements are used for db measurements. When the db meter is calibrated, a reference point, based on a specific power or value of voltage across a specified resistance, is selected to represent 0 db. Many electronic voltmeters use a db scale based on 1 milliwatt into a 600-ohm load to represent 0 db. Based on this reference point, various voltage readings could be made on the low AC voltage scale. To provide a single calibrated db scale for use on all db ranges, + db numbers corresponding to the voltage ratios existing between successive ranges and the low AC range are computed for each range. These numbers, shown on the front panel of the instrument, are added algebraically to each successive range reading to produce the correct value for that range.

16-12. It should be clearly understood that the term "decibel" does not, in itself, indicate power. It does indicate a ratio or comparison between two power levels that permits you to calculate the power. Often, it is more desirable to express performance measurements in terms of decibels by using a fixed power level as a reference. The original standard reference level was 6 milliwatts, but to simplify calculations, a standard level of 1 milliwatt has been adopted. Thus, when the expression *dbm* is seen, it should be understood that the reference level is 1 milliwatt.

16-13. *Vu meters.* The volume unit (vu) meter, used in audio equipment to indicate audio level, is a special kind of power meter. Its meter movement has a rapid rise and a slow fall, so that it follows the audio peaks and modulation envelopes. The unit of measurement is the volume unit, which is numerically equal to 1 db above or below the reference level of 1 milliwatt into a 600-ohm load. A change of 1 vu is, therefore, the same as a change of 1 dbm. It should be emphasized that a vu meter can always be used as a db meter; however, a db meter can be used as a vu meter only when the audio output is a steady tone. Some vu-meters are calibrated to read percentage of modulation, as well as volume units, when calibrated to the equipment with which they are used.

16-14. **Bolometer Bridges.** The measurement of power can also be made with a bolometer bridge instrument. A *bolometer* is a specially constructed element of temperature-sensitive material. The active material can be a short, ultra-thin wire (called a *barretter*), a semiconductor bead supported between two pigtail leads (called a *thermistor*), or a thin conducting film of small dimensions. The most common types of bolometers used to measure low power at high frequencies are barretters and thermistors.

16-15. When RF power is applied to a bolometer element, the power absorption by the element heats the element and causes a change in its electrical resistance. Thus, a bolometer can be used in a bridge circuit so that small resistance changes can be easily detected and power measurement accomplished by the substitution method (that is, substitution of DC or low-frequency power to produce an equivalent heating effect). A D'Arsonval meter movement is usually employed as the null indicator. According to one principle of measurement (the principle used in the *balanced bridge*), the bridge is initially balanced with low-frequency bias power; then RF power is applied to the bolometer, and the bias power is gradually removed until the bridge is again balanced. The actual RF power is equal to the bias power removed. According to another principle of measurement (the principle used in the *unbalanced bridge*), the bridge is not rebalanced after the RF power is applied. Rather, the indicator reading is converted directly into power by use of a calibration previously performed. Figure 87 illustrates the basic bolometer bridge circuit. The bolometer element must be: (1) physically small to be highly sensitive, (2) equally responsive to low-frequency and RF power, and (3) matched to the RF input powerline.

16-16. **Calorimeters.** Calorimeters (heat measuring devices) are the most accurate of all instruments for the measurement of high power.

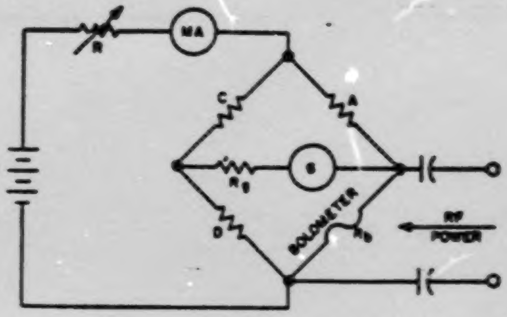


Figure 87. Basic bolometer bridge circuit.

They depend on the complete conversion of the input electromagnetic energy into heat. Direct heating requires the measurement of the heating effect on the medium, or load, terminating the line. Indirect heating requires the measurement of the heating effect on a medium or body other than the original power absorbing material. Power measurement with true calorimeter methods is based solely on temperature, mass, and time. Substitution methods use a known low-frequency power to produce the same physical effect as an unknown RF power being measured. Calorimeters are classified as *static* (or nonflow) types and *circulating* (or flow) types.

16-17. The static calorimeter uses a thermally shielded body and, since an isolated body loses little heat to a surrounding medium, the temperature increase of the body is in direct proportion to the time of applied power. The product of the rate of temperature rise in the calorimetric body and its heat capacity equals applied power. Figure 88 illustrates a static-type calorimeter.

16-18. Flow calorimeters are classified by (1) the type of circulating method used (open or closed), (2) the type of heating used (direct or indirect), and (3) the type of measurement performed (true calorimetric or substitution). Water or other calorimetric fluid is used only once in an open system. An overflow system is used to maintain a constant rate of flow. Closed systems recirculate the fluid continuously by means of a pump, and a cooling system restores the fluid to ambient temperatures prior to its return to the calorimeter. Closed systems are more elaborate, but this self-contained method permits the use of fluids other than water.

16-19. Flow calorimeters provide the primary standards for the measurement of high-power levels and, in conjunction with calibrated directional couplers, attenuators, power dividers, or other similar devices, serve to standardize medium- and low-power measuring instruments. The measurement time depends upon the required time for the entering fluid to reach the outlet where the rise temperature is measured.

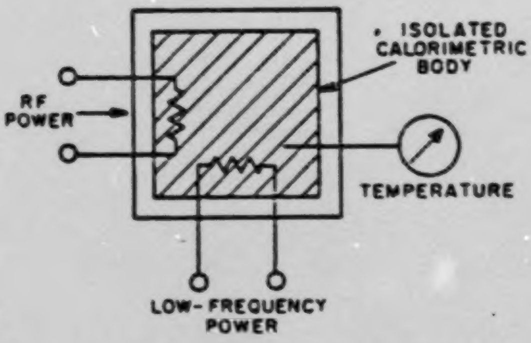


Figure 88. Static calorimeter.

16-20. The circulating fluid may serve in a dual capacity as the dissipative medium and coolant, using the direct heating method, or solely as a coolant, using the indirect heating method. Because of its excellent thermal properties and high dielectric loss at 1000 MHz or higher, water is normally used in both heating methods. Water is rarely used as the fluid at frequencies lower than 1000 MHz because of insufficient dielectric losses. The indirect heating method offers a wider frequency and power range coverage and can be used in substitution type measurements.

16-21. Substitution methods do not involve direct heat-dissipation measurement of moving fluid. Greater accuracy is obtained because known low-frequency power is substituted for unknown RF power, with all other measurement parameters remaining constant. The accuracy depends on the exactness of the low-frequency power determination and on the degree that all factors remain fixed during the substitution of one type of power for another. Figure 89 illustrates a flow calorimeter using low-frequency power substitution. Two different measurement techniques are possible with this type of meter: (1) the calibration technique and (2) the balance technique.

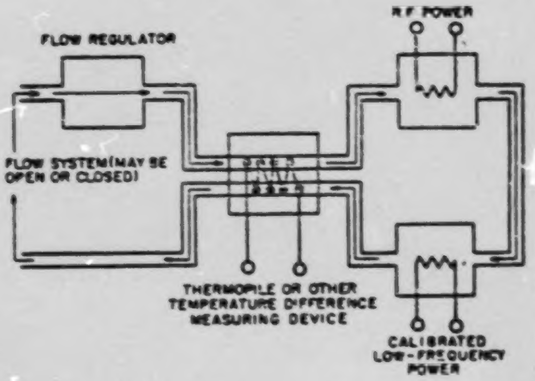

R F POWER
FLOW REGULATOR
FLOW SYSTEM (MAY BE OPEN OR CLOSED)
THERMOPILE OR OTHER TEMPERATURE DIFFERENCE MEASURING DEVICE
CALIBRATED LOW-FREQUENCY POWER

Figure 89. Flow calorimeter.

16-22. The *calibration technique* uses an adjustable known power to reproduce exactly the same temperature indication originally obtained by the unknown RF power measurement.

16-23. The *balance technique* uses an initial low-frequency power (P1) to provide a steady-state temperature rise in the calorimetric fluid.

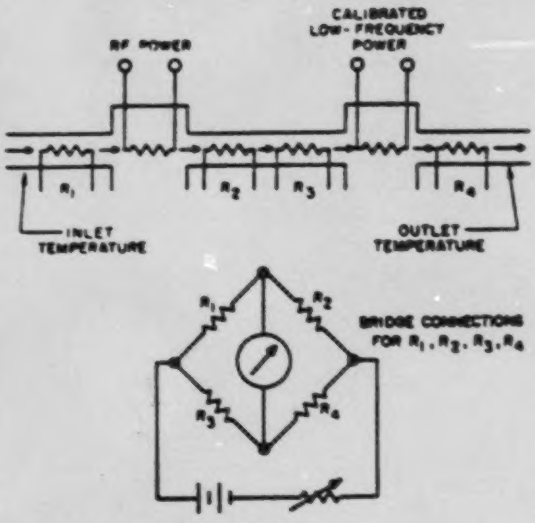

RF POWER
CALIBRATED LOW-FREQUENCY POWER
R1
R2
R3
R4
INLET TEMPERATURE
OUTLET TEMPERATURE
R1
R2
BRIDGE CONNECTIONS FOR R1, R2, R3, R4
R3
R4

Figure 90. Balanced flow calorimeter.

When unknown RF power is applied, the original power (P1) is reduced to a new power (P2) to maintain the same temperature indication. Therefore, the actual power equals P1 – P2. Figure 90 illustrates a widely used method of power measurement, using a balanced-flow calorimeter. Temperature-sensitive resistors are bridge connected as the thermometric elements and are balanced at ambient temperature prior to the application of power. Low-frequency balancing power and the unknown RF power are applied to maintain the bridge at null. This occurs when the temperature rise due to the unknown RF power equals the temperature rise which is due to the know low-frequency power.

16-24. Airflow calorimeters use the subsitution power principle and are used in the UHF region to measure power on the order of 20 watts. This instrument consists primarily of a coaxial line section containing a tungsten filament center conductor within an evacuated envelope, to act as both the low-frequency and RF load. A thermopile indicates the temperature difference between the forced air that enters and leaves the coaxial inclosure that houses the termination.

17. Frequency Test Instruments

17-1. There are several types of frequency test instruments which are useful to the electronics repairman. These are wavemeters, grid-dip meters, heterodyne (beat) frequency meters, and frequency counters.

17-2. **Wavemeters.** Wavemeters are of two basic types: (1) reaction and (2) absorption. Both types are passive; that is, both absorb part of the output power of the equipment whose frequency is undergoing measurement. The *reaction* wavemeter absorbs very little power and is, therefore, preferred for use when frequencies in low-power equipment are to be measured. An indication of resonance is supplied by the equipment undergoing measurement, usually in the form of an ammeter of suitable range. The *absorption wavemeter* is more accurate than the reaction wavemeter, but it absorbs slightly more power from the device under test. Since it tends to load the equipment undergoing examination, its use is generally restricted to high-powered equipment. The indicator of resonance, usually a meter or a lamp, is connected into the tank circuit of the wavemeter. When the ultra-high radio frequencies (300 to 3000 MHz) are reached, it is physically impossible to use the ordinary type of absorption wavemeter. The reason for this is that such small values of capacitance and inductance are required for resonance at these high frequencies, that it is not feasible to manufacture them. If the wavemeter type of frequency meter is to be used in this region of the radio-frequency spectrum, it is necessary to use either a resonant-cavity or resonant-line type of frequency meter.

17-3. For conducting preliminary adjustments on transmitters and for general experimental work, the simple *resonant-circuit wave-meter* is a valuable tool. However, wavemeters cannot be used where accurate measurements are required, because they tend to detune self-excited oscillator circuits to which they are coupled. The brightest lamp indication or highest meter indication normally registers the fundamental frequency. Therefore, this type of meter is very useful (1) for checking a transmitter to determine whether or not the master oscillator is operating close to the correct fundamental frequency, (2) for checking the neutralization of an amplifier, (3) for detecting the presence of radio-frequency parasitic oscillations, and (4) for determining

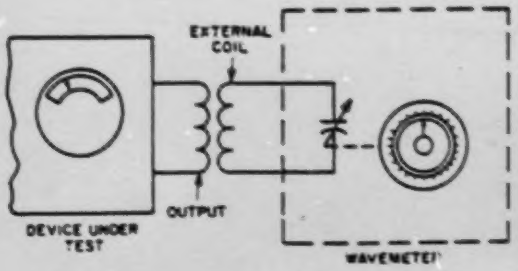


Figure 91. Reaction-type wavemeter.

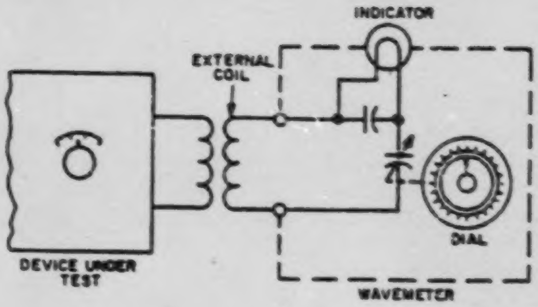


Figure 92. Absorption-type wavemeter.

radiated field strength in relative measurement terms.

17-4. *Reaction wavemeters.* The circuit of a reaction-type wavemeter, containing a coil and a variable capacitor, is shown in figure 91. The range of frequency measurement of the wavemeter is changed by the use of plug-in coils. The coil, which is external to the wavemeter, is loosely coupled to the circuit whose frequency is to be measured. The resonant frequency of the wavemeter is made equal to the frequency of the circuit under measurement by varying the capacitor. At some point within the frequency range of the capacitor-coil combination, the indicating device will indicate maximum or minimum deflection, depending upon the circuit location of the indicator. When the wavemeter is adjusted to the resonant point (maximum loading effect), it is important that the coupling be reduced to the point which produces a barely usable indication. If the coupling is not reduced, a sharp indication of resonance will not be obtained and a consequent error will be introduced.

17-5. *Absorption wavemeters.* The absorption wavemeter, shown in figure 92, is basically the same as the reaction wavemeter previously discussed. An inspection of figure 92 shows that the indicator has been included as part of the internal circuitry of the absorption wavemeter. The fixed capacitor, connected across the terminals of the indicating lamp, has a much greater capacitance than the variable capacitor. This large capacitance permits a voltage to be developed at resonance to light the lamp, and at the same time it has negligible effect on the resonant circuit because of its low reactance.

17-6. When this type of wavemeter is coupled into the circuit under test, care must be used as resonance is approached so that the lamp will not burn out. The dial should be rotated slowly and, as the lamp begins to glow, the wavemeter coupling should be reduced. For greater accuracy, the wavemeter should be coupled so that maximum brilliance is only a faint glow. A well-constructed instrument will provide an accuracy of 0.25 to 2 percent. Because of changes in capacitance or induction from vibration or from temperature and humidity changes, it is often necessary to recheck the calibration.

17-7. **Grid-Dip Meters.** It is often desirable

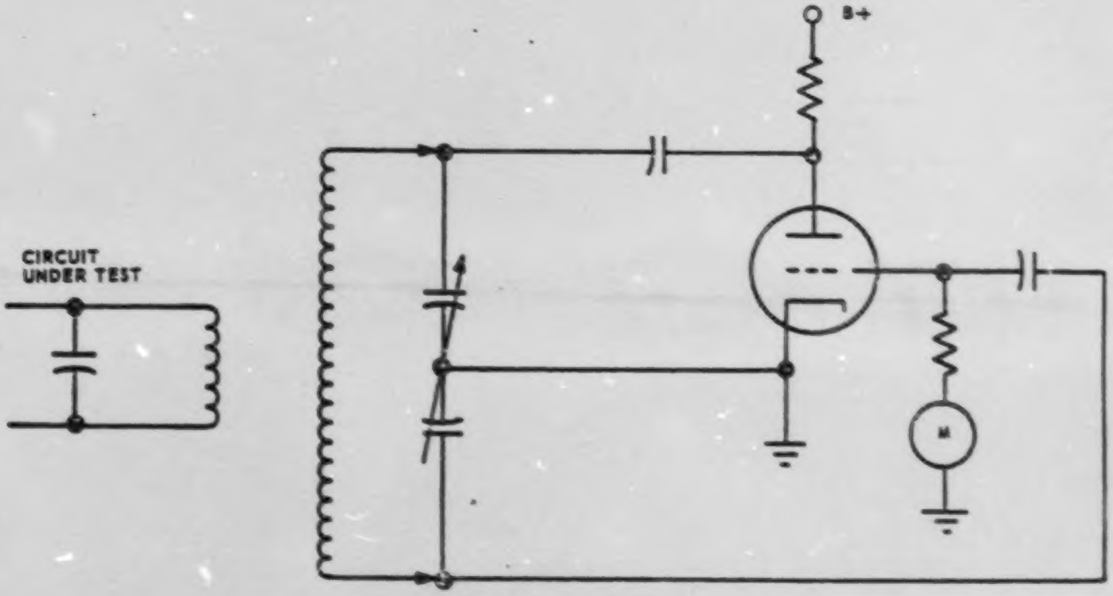


Figure 93. Grid-dip meter.

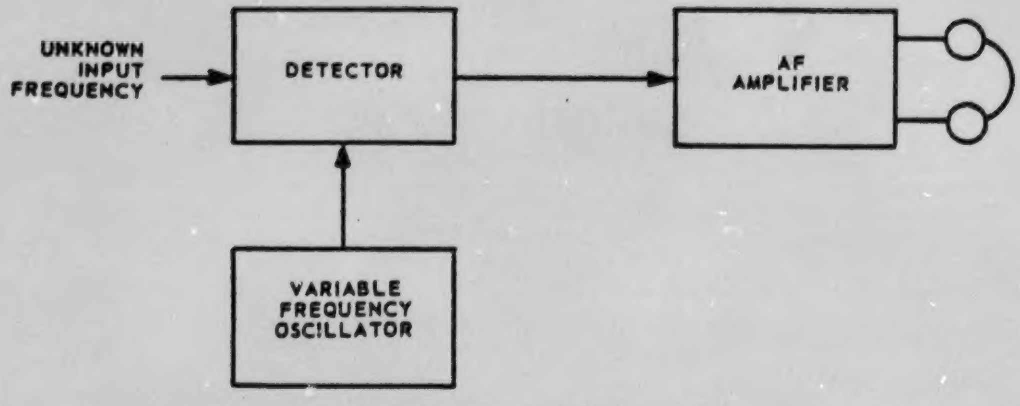


Figure 94. Block diagram of a basic heterodyne frequency meter.

to determine the approximate frequency of a tuned circuit before power is applied to it. Such a determination can be made with an instrument called a grid-dip meter. This instrument is essentially an oscillator, as shown in figure 93. The variable capacitor is calibrated in kilohertz or megahertz. To make a measurement, the coil is coupled inductively to the tuned circuit under test. The variable capacitor is adjusted until the meter indicates a minimum grid current. At this point, the tuned circuit under test is absorbing the maximum amount of energy from the grid-dip oscillator. Therefore, the grid-dip meter is tuned to the frequency of the circuit under test. This frequency is read directly on the calibrated dial of the instrument.

17-8. Since the grid-dip meter generates a signal, it is an active instrument. A wide frequency range is obtained by using plug-in type coils. It is designed so that the coil can be inductively coupled to the circuit under test. For maximum accuracy, the grid-dip meter should be loosely coupled so that the dip in grid current is distinct.

17-9. **Heterodyne-Frequency Meters.** Frequency can be measured more accurately with a specially designed instrument called a heterodyne-frequency meter. It is a precision instrument that measures an unknown frequency by heterodyning it with a known frequency which is obtained from a calibrated, high-precision, variable-frequency oscillator (VFO). When zero beat is obtained, the unknown frequency is that of the VFO. The zero-beat indicator in test equipment of this type is generally a pair of headphones; however, some heterodyne-frequency meters employ an oscilloscope for this purpose.

17-10. *Operation*. The basic heterodyne meter (shown in the block diagram of figure 94) is a calibrated variable oscillator with associated circuits, which heterodynes against the frequency to be measured. Coupling is arranged between the frequency meter and the output of the device under test. The calibrated oscillator is then tuned so that the difference between the oscillator frequency and the unknown frequency is in the audio-frequency range. This difference in frequency is known as the *beat frequency*; when detected and amplified, it is audible in a headset. This region of beat frequencies is shown diagrammatically in figure 95. Starting at point A on the figure, a very high-pitched note can be heard in the headset. As the two frequencies are brought closer to the same value (decreasing difference), the tone decreases in pitch down to point B. Here the tone is replaced by a series of rapid clicks.

17-11. As the process continues still further, the clicks decrease in rapidity until they stop altogether at point C. This is the point of *zero*

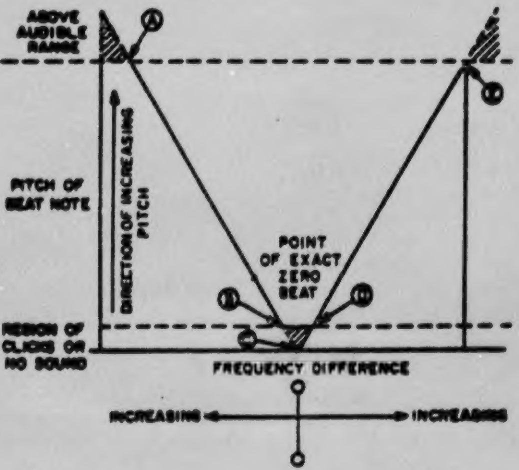


Figure 95. Beat frequency diagram.

beat, where the frequency generated in the calibrated oscillator is equal to the frequency of the unknown signal being measured. For all practical purposes, zero beat is obtained when clicks are heard at rather infrequent intervals, since it is extremely difficult to maintain a condition of absolute silence in the headset over a prolonged interval of time. When the incoming signal is fairly strong, the clicks are sharp and distinct. When the signal is weak, the zero-beat condition is evidenced by a slowly changing swishing or rushing sound in the headset.

17-12. If one of the two original frequencies is varied still further, the rapidity of clicks increases to point D. At this point, a low-pitched tone is heard. Further variation in the same direction causes a gradual increase in pitch until point E is reached, where the beat note becomes inaudible again. This region of increasing pitch on both sides of the zero beat is characteristic of this procedure.

17-13. After the zero beat is obtained, the dial reading, when properly interpolated, corresponds to the frequency under measurement. *Aural beats*, heard by the use of headphones, may be acceptable to obtain an approximate indication of zero beat. It should be apparent that this method leaves a small doubtful region in the shaded area, BCD on figure 95. The generally accepted audible range of the normal human ear has a lower limit of 15 to 20 hertz. Under these circumstances, the area BCD could represent an error of 30 to 40 hertz, or more in some cases.

17-14. To overcome this type of difficulty, simple oscilloscope circuitry is included as a part of some heterodyne-frequency meters to provide exceptional sensitivity. The sensitivity of the device increases with the amount of amplification preceding the cathode-ray tube. No vertical deflection occurs at the zero-beat condition. An effective indicator suitable for incorporation within a frequency meter uses an electron-ray indicator tube. The sensitivity of this simple device is excellent. Other types of visual indicators are vacuum-tube voltmeters, rectifier-type audio-frequency voltmeters, and neon lamps.

17-15. The variable-frequency oscillator (VFO) is the source of the signals used in making frequency checks on receivers and transmitters. One of the prime requisites of the variable-frequency oscillator is stability of oscillations. As you know, there are various means of obtaining this stability.

17-16. The use of plug-in coils or switches is generally unsatisfactory since they are mechanically unstable. Many VFOs are tuned by having their tuning capacitor rotated by a precision-type split bronze worm wheel and a hardened stainless steel worm gear. This portion of the tuning unit is not readily replaced without materially affecting the calibration of the frequency meter. When construction throughout the meter is sturdy and high-grade ceramics are used as insulators in the oscillator circuit, a precise frequency calibration will hold over a long period of time.

17-17. The circuit usually employed as the variable-frequency oscillator is the electron-coupled oscillator. One of the reasons for this choice of oscillator circuit is that the output frequency can be made very stable with respect to loading conditions in the output circuits. Another reason is that with the use of screen-grid tubes, the generated frequency can be made relatively independent of tube supply potentials, as long as the ratio of the plate-to-screen potentials is maintained near the desired value. Sometimes frequency-determining elements of the VFO are inclosed within a temperature-compensating oven to prevent the effects of ambient temperature.

17-18. *Crystal checkpoints*. Accumulated errors from changes in temperature, humidity, and power-supply potentials, as well as rough handling, can be corrected at a number of places throughout the tuning range of the instrument. This can be done by means of the beat notes between the fundamental frequency of the VFO (or its harmonics) and the fundamental frequency of crystal oscillator (or its harmonics).

17-19. The harmonics of both oscillators are present in an unbroken series, with decreasing amplitude as the order of the harmonic increases. Since any harmonic of one oscillator beating with any harmonic of the other can produce a beat note, there is considerable variation in the strength of the beat notes as the dial is tuned across its tuning range. For convenience and accuracy, the relatively strong beat notes are chosen as crystal checkpoints.

17-20. By calibrating and correcting at a crystal checkpoint, the heterodyne-frequency meter is adjusted so that the frequency generated by the variable-frequency oscillator at a given dial setting is actually the same as the frequency listed opposite the dial setting in the calibration book.

17-21. *Calibration book*. The calibration book is a very important part of the frequency meter; in fact, the book is so important that it bears the same serial number as the instrument itself. The information contained within this book is a list of the dial settings and the corresponding frequencies produced by the meter at those dial settings. Concise operating

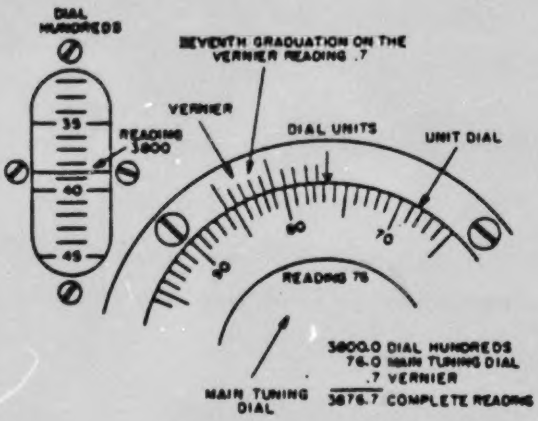

DIAL HUNDREDS
SEVENTH GRADUATION ON THE VERNIER READING .7
VERNIER
READING 3800
DIAL UNITS
UNIT DIAL
35
40
45
50
60
70
READING 76
3800.0 DIAL HUNDREDS
76.0 MAIN TUNING DIAL
.7 VERNIER
3876.7 COMPLETE READING
MAIN TUNING DIAL

Figure 96. Heterodyne frequency meter dial.

instructions for the frequency meter are also included. Crystal checkpoints are usually entered in this book in red-ink numerals at the top and bottom of each page, and apply only to the settings on that page, while the black-inked entries are the settings for the actual measured frequency.

17-22. *Main tuning dial.* The main tuning dial is an assembly to two mechanical drive units connected to the variable-frequency oscillator tuning capacitor. A drum dial, located behind a small window (see figure 96), indicates the setting of the main tuning dial in units of 100 per division. The main tuning dial itself is the large drive dial on the front panel of the meter. It is calibrated in units of 1 per division. For one complete revolution of the main tuning dial, representing 100 units, the drum dial will move one division. A vernier is mounted in a fixed position above and on the outside edge of the main tuning dial. The vernier indicates tenths of a division of the main tuning dial.

18. Frequency Counters

18-1. The frequency counter is an electronic measuring instrument designed to register and display, by digits, the number of cycles that occur during a specific time interval. This instrument permits the rapid, direct measurement of the frequency of period of a signal.

18-2. Frequency counters have predominantly used electron tubes, but there is a definite trend toward the increased use of transistors and magnetic devices. Although counters differ in many details, they are all essentially the same. The differences are primarily those of capabilities and range. This, of course, means that their circuitry differs in complexity. Since the details of difference are too numerous to discuss in this course, let us give our attention to the principles of operation and the essential sections contained within these instruments.

18-3. **Functional Sections.** Figure 97 shows a block diagram of a basic frequency counter. The signal to be measured is fed into the *input section*, where it is amplified and shaped before reaching the *gate section*. The purpose of the *time-base section* is to generate a stable square wave of known frequency. The output from the time-base section is modified by the gate section to provide a pulse for the *reset section*, and to develop a precise time interval for transfer of the unknown signal to the *display section*. The display section counts the number of pulses and gives a digital readout. This, in

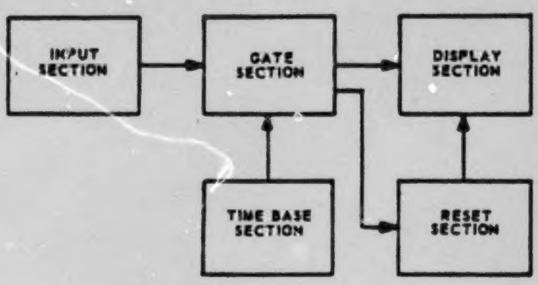

INPUT SECTION
GATE SECTION
DISPLAY SECTION
TIME BASE SECTION
RESET SECTION

Figure 97. Block diagram of a frequency counter.

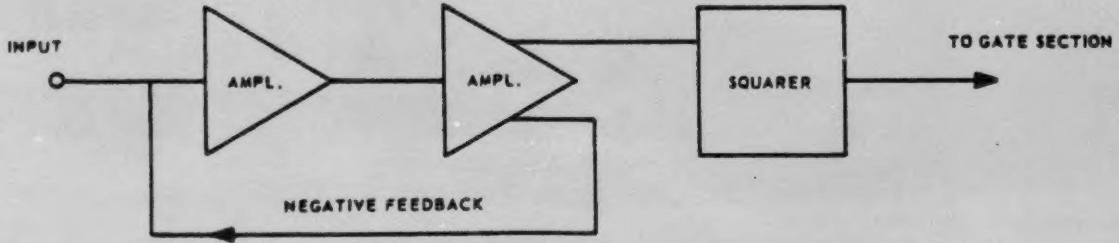

INPUT
AMPL.
AMPL.
SQUARER
TO GATE SECTION
NEGATIVE FEEDBACK

Figure 98. Input section.

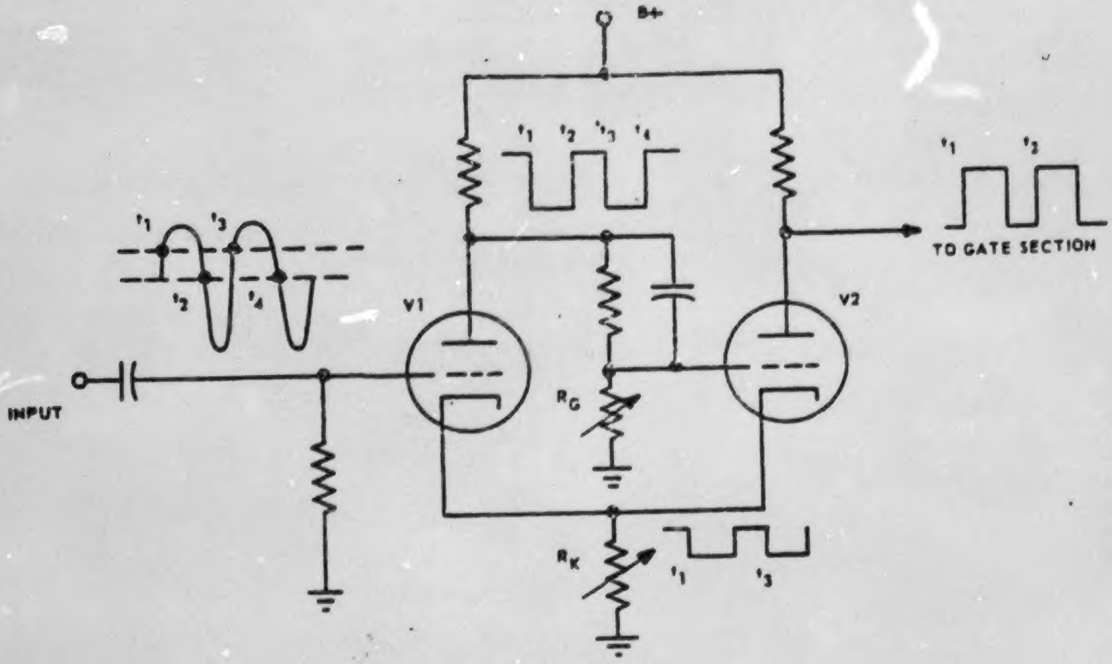


Figure 99. Schmitt trigger circuit.

brief, is what takes place; but you need to know more about each of the sections to understand how a counter operates.

18-4. *Input section*. The input section consists of one or more amplifiers and a squarer stage. Figure 98 shows two stages of amplification preceding the squarer. These amplifiers are conventional types; therefore, we need not analyze them. The indicated negative feedback may be obtained in a number of ways to increase the input impedance and stabilize the system. The squarer shapes the signal into a near perfect rectangular waveform. Because the Schmitt trigger circuit is particularly well suited for this, it is commonly used. A review of the operation of this type of squarer will reveal why it is an excellent waveshaping circuit for counters.

18-5. The basic Schmitt trigger circuit is actually a bistable multivibrator (see figure 99). We have chosen to use electron tubes for explanation purposes, but bear in mind that transistors (NPN or PNP types) are also used. Although component values and bias voltages are quite different, the operating principles and circuit configuration are fundamentally alike for electron tubes and transistors. Bias adjustments are critical for proper operation. Switching from full conduction to cutoff of the amplifying device is virtually instantaneous. This rapid switching is a very desirable feature, of course, since it produces an output signal with steep leading and trailing edges. Let us now briefly discuss why biasing is critical and how rapid switching occurs.

18-6. Refer again to figure 99. Note that in a basic Schmitt trigger circuit, the plate of V1 is coupled via a voltage divider to the grid of V2. The capacitor connected across the upper portion of this voltage divider is to increase the initial response of V2 to a voltage change on the plate of V1. Note also that the cathode resistor is common to V1 and V2; it therefore provides feedback coupling in addition to bias for both tubes. The bias is established by Rk and Rg so that V1 is cut off and V2 is conducting its maximum. Consequently, the plate of V1 is at a high voltage (practically B+) and the plate of V2 is at a low voltage. This is the normal stable state when there is no signal input to the circuit shown.

18-7. We have intentionally distorted the input signal in figure 99 to point out that the shape of the input signal is not critical, which is another advantageous feature of this circuit. Tube V1 is biased below cutoff to a degree that prevents noise signals from actuating the circuit. This adjustment is important, since only the signal under test should trigger the circuit. Once the bias is adjusted, V1 will be driven into conduction at a prescribed signal voltage. We see, in figure 99, that this voltage is reached at time T1, and V1 conducts. Instantaneously, the plate voltage of V1 decreases, thereby decreasing the grid voltage of V2; thus, the cathode voltage of V2 decreases. Because the cathodes of V1 and V2 are direct coupled, this decrease in cathode voltage effectively decreases the bias on V1 and causes it to conduct harder. In other words, we have regenerative feedback, which accounts for the rapid switching action from one stable state to the other state. Between the times T1 and T2, V1 is conducting and V2 is cut off. At time T2 the process works to reverse the stable states of the tubes, V1 is driven to cutoff, and V2 goes to full conduction. Study the waveforms in figure 99 and note that at times T3 and T4 switching occurs exactly as described at times T1 and T2, respectively. The recurring rectangular output is seen to have a frequency which is identical to that of the input signal; the period is the time interval between T1 and T3.

18-8. Schmitt trigger circuits vary a great deal in design, depending upon the requirements that must be met, such as switching times and driving voltage. Like other multivibrators, the output can be taken from the plate of either tube. Modifications in Schmitt trigger circuits, however, do not change the operating principles that we have covered.

18-9. The output from the Schmitt trigger circuit or another type squarer is fed out of the *input section* into the *gate section*. Before discussing the gate section, however, we need to learn what is contained within the *time-base section*, since the output of this section is also fed into the gate section. The precision of the counter is greatly dependent upon the operation of the units within the time-base section.

18-10. *Time-base section*. The units that comprise the time-base section are shown in figure 100. You know there are many kinds of sinusoidal crystal oscillators. Whichever kind is used, its crystal is contained within a temperature-controlled oven to insure a high degree of frequency stability. A constant output frequency is of *utmost* importance. Loading effects upon the oscillator are reduced by feeding its output into a buffer amplifier. We have shown only one stage of amplification, but you should realize that more amplifiers may be employed. The squarer shapes the sine wave generated by the oscillator. Often, the squarer is simply a limiter stage that clips the positive and negative alternations to produce a square wave. The square-wave output is applied to a series of decade frequency dividers.

18-11. Each frequency divider steps down the frequency by a fixed ratio—in this case 10:1. One popular way is to differentiate the output of the squarer and to use every tenth positive- or negative-going pulse to trigger a monstable multivibrator. Since you should already know how frequency divisions can be accomplished, we will not discuss circuitry.

18-12. Our block diagram shows six frequency dividers (see figure 100), each of which gives an output square wave that is one-tenth the frequency of its input. By a selector switch, the desired time period is chosen and sent to the gate section. The time markings on the selector switch correspond to the period of the respective frequencies. Less dividers may be used if a wide range is not necessary. Counters designed for high-frequency measurements use higher frequency crystals and may also have a heterodyne unit to extend its low-frequency range.

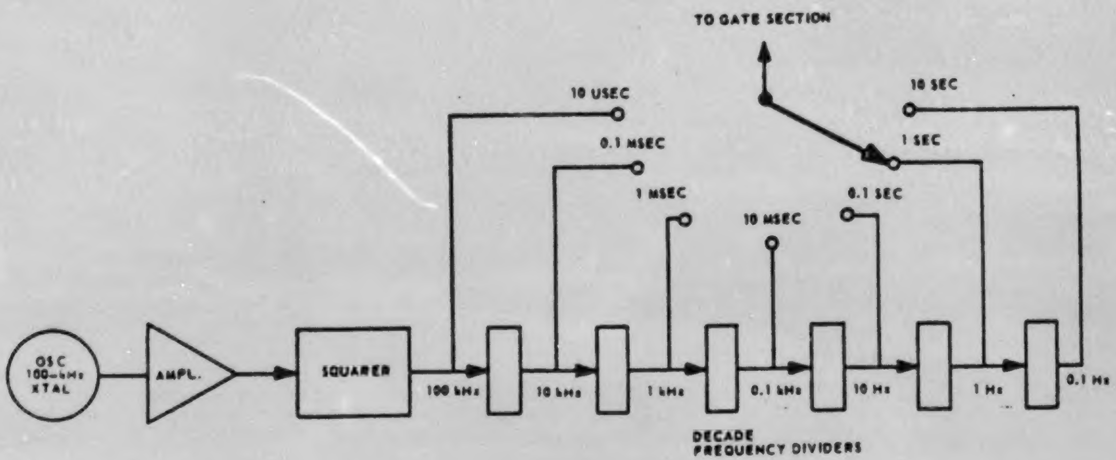


Figure 100. Time-base section.

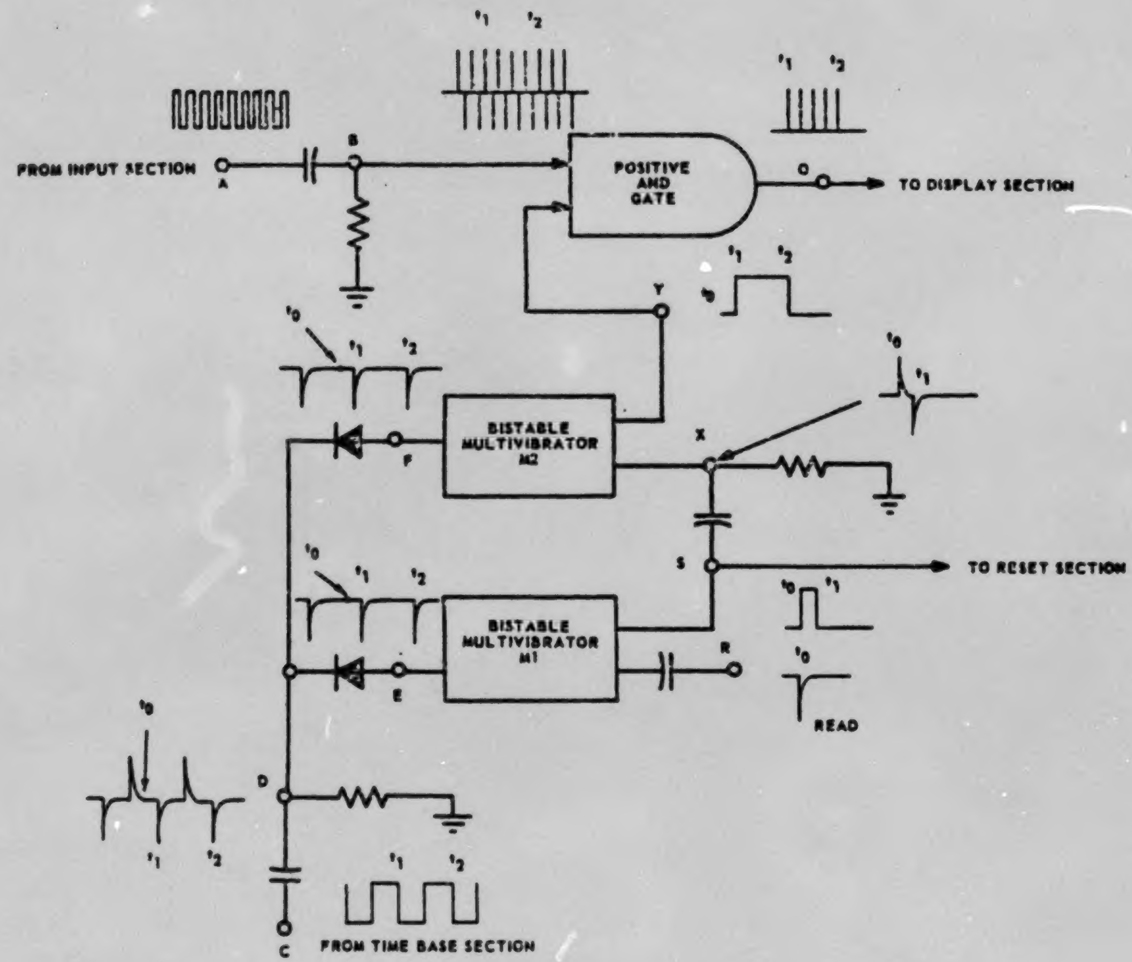

t1
t2
t1
t2
FROM INPUT SECTION
A
B
POSITIVE AND GATE
O
TO DISPLAY SECTION
t1
t2
Y
t0
t0
t1
t2
BISTABLE MULTIVIBRATOR M2
F
X
t0
t1
S
TO RESET SECTION
t0
t1
t2
t0
t1
BISTABLE MULTIVIBRATOR M1
E
R
t0
READ
t0
D
t1
t2
t1
t2
C
FROM TIME BASE SECTION

Figure 101 Gate section.

18-13. *Gate section*. Here, again, we are confronted with numerous ways of accomplishing the desired results. The system that we will explain demonstrates the necessary functions that must be performed by the gate section. Refer again to figure 97 and note that the gate section has two inputs (one from the input section and one from the time-base section) and two outputs (one to the reset section and one to the display section). Recalling what we previously said, you know that both inputs are rectangular waveforms. Let us now find out how these inputs are used and what outputs are produced.

18-14. At point A in figure 101, we see the input rectangular waveform that has the frequency of the signal under test. After being differentiated, it appears at point B as a series of alternately positive and negative pulses. These pulses are applied to a circuit that gates when two positive inputs are received simultaneously (this circuit is called a positive AND gate). This gate is normally disabled because the input from point Y is normally low. Both multivibrators, M1 and M2, are normally set to have a low output at points S and Y, respectively.

18-15. Looking now at point C in figure 101, we see the input waveform from the time-base section. This waveform is differentiated as shown at point D. Because of the diode in series with the input to M1, only the negative-going pulses (called clock pulses) appear at point E. These pulses will not actuate M1 when it is in its normal stable state. The same is true for M2, which is receiving negative-going clock pulses also.

18-16. Thus far, we have established the normal state of affairs. The AND gate is disabled, so no output pulses appear at point 0 to be fed into the display section. Moreover, until a change of state is effected in M1, there is *no* pulse at point S to be fed out into the reset section.

18-17. Let us now apply an input (called a *read pulse*) to point R. This pulse actuates M1 at time T0. Immediately the voltage at S goes high and stays high until time T1. At T1, the clock pulse to M1 (point E) is effective and restores M1 to its normal state. Note that this action has produced a positive pulse at point S which goes out to the reset section. This same pulse is differentiated and appears at point X as a positive and a negative trigger pulse. The positive trigger pulse does not affect M2, but the negative ones do. Thus, at time T1, point Y goes high and stays high until time T2, when the clock pulse to point F restores M2 to its normal state. During the time interval T1 to T2 (which is the period of the time-base signal), the AND gate is enabled. This means that pulses appear at point 0. These pulses, which have the frequency of the signal under test, are fed out to the display section, where they are counted. Therefore, a count is made for the precise time interval, T1 to T2. When Y returns to a low voltage at time T2, the entire section is back to its normal state. No further action occurs until another read pulse is injected at point R. Read pulses may be applied by manual operation or by automatic recycling controls.

18-18. The time relationships of the signals can be readily seen in figure 102. Study this figure in conjunction with figure 101. Note particularly that the output to the reset section (point S) precedes the output to the display section (point 0). Although we show only five output pulses at point 0, you should realize that several thousand or more pulses may occur during the time interval T1 and T2.

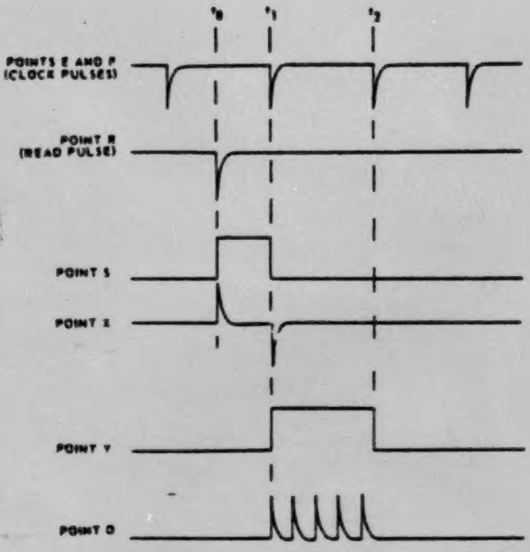


Figure 102. Frequency counter waveshapes.

18-19. As you know, there are other gating arrangements that could produce similar outputs. Multivibrators may be tube or transistor types. Sometimes magnetic bistable devices are used in place of multivibrators. Nevertheless, the system we have just discussed should give you a general idea of the purpose and function of the gate section.

18-20. *Reset section*. The function of this section is to reset (or preset) the counting units within the display section. Remember that an output pulse from the gate section is fed into the reset section before the display section receives its input signal. This is necessary, of course, because the counters must be cleared (reset to zero) prior to the initiation of the counting period.

18-21. The reset section consists of a mechanical or electronic relay, e.g., a thyratron tube and associated circuitry to feed reset pulses to all of the counting units. By shaping and amplifying the input pulse from the gate section, this relay develops triggers of sufficient power to drive all the counting units back to their zero setting. Each time a read pulse is injected into the gate section, the reset section is actuated. Therefore, if the read is automatic, so also is the reset.

18-22. *Display section*. This section generally contains five or more counting units connected in cascade. These units total and display the number of pulses fed from the gate section during the counting period.

18-23. A counting unit recycles on every tenth pulse. More specifically, the unit registers nine pulses and resets itself to zero on the tenth pulse. When it resets, it sends a pulse (called a *carry*) to the next counting unit. Since all the units operate in an indentical manner, each subsequent unit registers a count which is greater by a factor of 10. Thus, the first unit registers ones; the second, tens; the third, hundreds; the fourth, thousands; the fifth, ten thousands; and so on. Five counting units will register a maximum of 99,999.

18-24. The display is generally an in-line readout of the frequency count (see fig. 103). This type readout can be obtained in several ways. The Nixie indicator, patented by the Burroughs Corporation, is a popular device used to provide in-line readout. It is a gas-filled tube that has one anode and 10 stacked cold cathodes that are shaped like numerals from 0 to 9. Each cathode has a separate input terminal. When a voltage is applied between the anode and any one of the cathodes, an

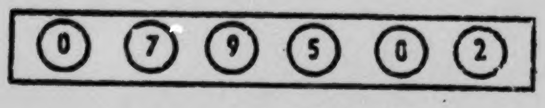


Figure 103. In-line readout.

ionization glow appears around the energized cathode. Thus, the cathode's numeral shape is illuminated to provide a visual readout.

18-25. The display illustrated in figure 103 consists of six Nixie indicators. The count displayed shows the frequency of the signal under test to be 79,502 Hz, if the counting time is 1 second. If, however, the counting time is 10 seconds, the signal frequency is 7,950.2 Hz.

18-26. **Measurements.** As you have observed, most frequency counters are designed to measure a wide range of frequencies. Therefore, let's see how greater accuracy can be attained by using the counter wisely.

18-27. Let us assume, for example, that a counter has a display of five digits, as illustrated in figure 104. We will also assume that when the time interval selector switch is set at 0.1 sec, a reading of 08573 is obtainable (see fig. 104,A). If we know the frequency is below 100 kHz, then this reading means that the signal frequency is 85,730 ± 10 Hz, since the least significant digit (3) may be nearly a full count off either way. By moving the selector switch to 1 sec, a more accurate reading of 85,737 ± 1 Hz is obtained (see fig. 104,B). If the counter has a 10-sec selector switch position, a still more accurate reading can be obtained, but you must realize that the most significant digit (8 in this case) will not be displayed. The readout (see fig. 104,C) of 57374 will, therefore, mean the frequency is 85,737.4 ± 0.1 Hz; the digit 8 is known from the previous reading. By taking successive readings in this manner, you can improve the accuracy of measurement appreciably.

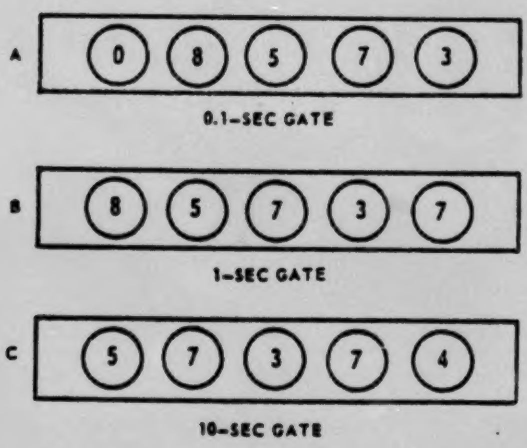


Figure 104. Reading sequence.

18-28. Ordinarily, 10 sec is the longest time interval (gate) available. This limits the accuracy obtainable for low-frequency measurements since relatively few pulses are counted during the time interval. Suppose the unknown signal frequency is between 10 Hz and 100 Hz. If the longest time interval used is 10 sec, the reading will be off from 0.1 to 1 percent. If the signal frequency is between 1 Hz and 10 Hz, the accuracy is from 1 percent to 10 percent off. So you see the lower the frequency, the lower the accuracy.

18-29. To attain an accurate measurement of a low-frequency signal, provision can be made for the counter to measure the period of the unknown signal. This method is quite simple and easily accomplished. The inputs to the gate section from the input section and time-base section are interchanged by a switch (see fig. 105). This makes the unknown signal establish the gate time for counting the frequency of the time-base signal. By using a high-frequency time-base signal, the counting units will register a large number of pulses during one period of the unknown signal. The period of the unknown signal. The period of the unknown signal can be determined, since each pulse counted represents a known amount of time. For example, let us assume a readout of 100,000 when the time-base selector is set on 10μsec (100-kHz time base signal). From this reading, we know that 100,000 pulses were counted. Since each pulse represents 10 μsec, the time interval is 100,000 × 10 μsec = 1,000,000 ± 10 μsec. This time is the period of the unknown signal; thus, 1 ± 0.00001 Hz is the unknown signal frequency. The accuracy of this measurement is 1 part in 100,000, or 0.001 percent. By comparison, if the unknown signal frequency is counted during the longer time-base period of 10 millisec, a readout of 00100 is obtained and the accuracy is 1 part in 100, or 1 percent. So we note a marked difference. Even greater accuracy can be achieved with the period measurement method in the low-frequency range if a 1-megahertz output is avilable from the time-base section. A 1-MHz signal will provide 1-μsec counts and, for the case cited, an accuracy of 0.00001 percent.

18-30. The ratio of two frequencies can be determined with a counter by letting the lower frequency establish the time interval (gate) and feeding the higher frequency into the input section. The higher frequency is counted during one peroid of the lower frequency. This count is actually the ratio of the higher to the lower

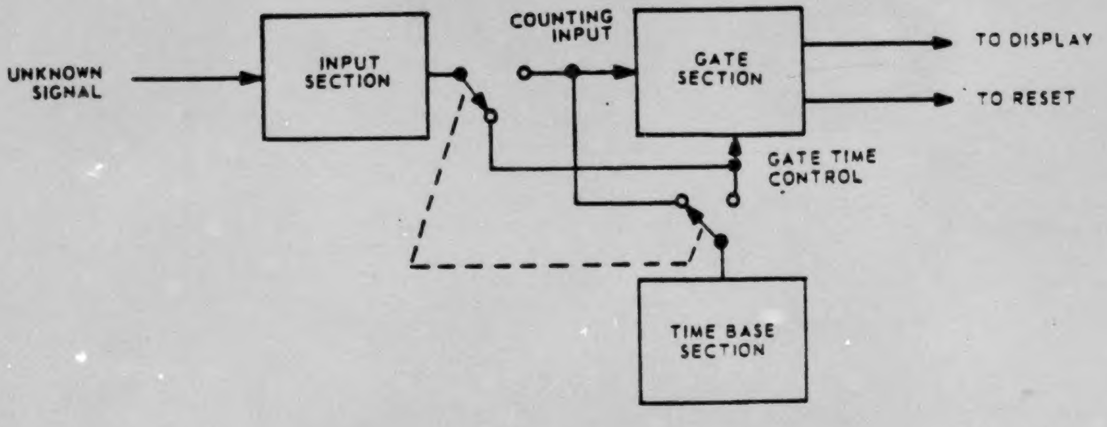


Figure 105. Period counter arrangement.

frequency. For example, if a 40-Hz signal is used to establish the time gate and a 20-kHz signal is counted, 500 hertz of the 20 kHz will be counted and displayed. This readout, 500, is the ratio 20 kHz/40 Hz.

18-31. Some counters are designed so that the time gate can be started by one signal and stopped by another. This capability is valuable for certain types of measurements. Such counters are called *time-interval meters*..

18-32. As mentioned earlier, counters are made to be very versatile. The usefulness of this instrument depends on your knowledge of the counter's capabilities and an understanding of the matters which we have just discussed.

19. Signal Generators

19-1. Since signal generators comprise a large and diverse group of test equipment, we will highlight their important features and describe them in a general manner. A signal generator usually consists of three major sections: (1) a variable-frequency oscillator with a meter which indicates its output level, (2) a modulating circuit, and (3) an output attenuator. The circuits are usually shielded to prevent the oscillator from radiating its signal to the equipment under test. When the switch is in the CW position, the output of the oscillator is a continuous modulated wave.

19-2. **The Oscillator**. In most signal generators, the oscillator is variable over a specific frequency range. When the equipment is designed for a special purpose, however, the oscillator may generate one or more specific frequencies.

19-3. The oscillator is made as stable as possible. As you know, stability is difficult to achieve when a VFO is employed. For this reason, some signal generators have a crystal oscillator which provides a standard reference frequency for the VFO. The VFO can be compared with the standard prior to using the test equipment, and any deviations in frequency can be corrected.

19-4. An LC-type oscillator is generally used to generate frequencies below 300 MHz. A Hartley or modified Hartley oscillator circuit is very popular. Above 300 MHz, a klystrom-type oscillator is commonly used because it provides a highly stable UHF output. Band switches are used to place different components of various values into the oscillator circuit so that the oscillator can operate over a wide range of frequencies.

19-5. **The Modulator.** Most signal generators have circuits to modulate their output. AM or FM may be used, depending upon the purpose for which the test equipment is designed. Three types of AM are employed: sinusoidal, square wave, and pulse. The sinusoidal type of modulation is most often used with the LC oscillators. Reflex klystron oscillators are modulated with a square wave to minimize incidental frequency modulation. Pulse modulation is frequently found in signal generators that produce simulated signals for various types of electronic equipment. When FM is used, the modulator varies the output frequency with a sine wave or with a linear sweep signal.

19-6. **Output Attenuator.** The output attenuator is an important and useful part of a signal generator. When a signal generator does not have a calibrated attenuator, the strength of the output signal is not known and the usefulness of the test equipment is limited.

19-7. The two types of attenuators commonly used are the resistor and the waveguide. Both are suitable for frequencies below 200 MHz, but the waveguide type is used almost exclusively above 200 MHz. The attenuator may be calibrated in one continuous range, but it is not uncommon for it to be calibrated in several steps. To prevent stray radiation from affecting the calibrated output, the attenuator should be well shielded. The accuracy of the attenuator depends upon the requirements. A high degree of accuracy is obtainable with a waveguide because its attenuation is determined by its physical dimensions.

20. Calibration and Repair of Test Equipment

20-1. The accuracy and performance of test equipment in your shop can mean the difference between a system that is functioning properly and one that is just getting by and not fulfilling its mission responsibility. As a repairman, you will be responsible for the equipment assigned to your shop. Operating instructions are sometimes found on the front cover of the test equipment; however, explicit instructions are contained in the −1 series of applicable technical orders (TOs). To insure that the system is operating at its maximum capability, it is mandatory that you be thoroughly familiar with the operation of the test equipment necessary to maintain the system at its peak performance.

20-2. There is a −1 technical order for each piece of test equipment you have in the shop. To obtain the necessary TOs, check TO O−1−33 (test equipment index) for a listing of publications applicable to the test equipment in your inventory. The missing TOs should be ordered through the channels established by your organization.

20-3. **Categories of Test Equipment.** For maintenance purposes, test equipment is divided into four categories. These are:

(1) Category I. Operational equipment installed in systems, subsystems, or equipment whose performance parameters are to be measured, verified, or tested.

(2) Category II. Peculiar precision measurement equipment used to check out, maintain, and calibrate Category I equipment. ("Peculiar" is applied to precision measurement equipment designed for and used with only one system, subsystem, or equipment, as contrasted with "common" items, which have general-purpose cross-system application).

(3) Category III. Common commerical and military precision measurement equipment used for maintenance, troubleshooting, testing, verification, and calibration of Category I and II equipment.

(4) Category IV. Standards and accessories used to calibrate Category II and III equipment. This equipment normally is located in and used by the base Precision Measurement Equipment Laboratory.

20-4. **Responsibilities for Test Equipment.** There are two organizations that have the primary responsibilities for maintaining all equipment in Categories I and II. These are (1) the using organization of which you are a part and (2) the bases' Precision Measurement Equipment Laboratory (PMEL). As part of the using organization, you have the responsibility for the calibration of all Category I and II equipment, with the following exceptions:

- Base PMEL calibrates all general-purpose and commercial Category II test equipment that can be moved to the PMEL. This does not include test equipment that must be calibrated while it is in your bench equipment.
- Maintenance of test equipment that requires special skills or special equipment (whether it be Category I or II) that is available only at the PMEL is the responsiblity of the base PMEL.

20-5. If you are in doubt as to whose area of responsibility a particular piece of test equipment falls into, go to your technical order file and look it up in TO 33K-1-100, *Responsibilities and Calibration Measurement Areas.* This TO lists all test equipment in the Air Force inventory, tells who is responsible for its calibration, lists any applicable TO containing the procedures for calibration, and lists the maximum number of days between required calibrations.

20-6. **Calibration of Test Equipment.** The PMEL should automatically reschedule your test equipment and call for it when calibration is required. If you should determine that calibration is required sooner than the scheduled date, then you must contact PMEL and have them reschedule that particular test set. When possible, regular calibration requirements must be reported by you to the PMEL to insure prompt compliance.

20-7. Test equipment that is an integral part of your equipment and cannot be removed, but which requires special skills and equipment for calibration, may be calibrated by the using organization with the assistance of PMEL personnel.

20-8. You are a part of the lowest echelon in the test equipment calibration ladder. Each higher step in the ladder has standards available to be used in the calibration of test equipment. The standards of each next higher echelon can then be used to check the standards of the lower echelons. At the top of this ladder is the National Bureau of Standards for Electrical and Electronics Equipment, Boulder, Colorado, and the National Bureau of Standards for Electromechanical and Dimensional Equiment, Washington, DC.

20-9. You may have standards in your shop; if so, these standards are called *shop standards*. A shop standard is defined as a precision measurement equipment known to have been officially calibrated and certified for use as a comparison in checking other items in the maintenance shop. These standards are not used for routine maintenance functions unless an emergency exists or all like items are inoperative.

20-10. It is extremely important that you be thoroughly familiar with your test equipment. Knowing how to use it effectively and care for it properly cannot be overemphasized. Properly used, it will provide you with years of dependable service. Know its capabilities, and it will aid you immeasurably in the performance of your equipment maintenance.

20-11. At this time work the chapter review exercise for Chapter 5 in your workbook.

CHAPTER 5

Electron Tube and Semiconductor Testing

TO BE OF practical use in the field, a tester must provide a simple means to appraise the condition of an electron tube or semiconductor. A field-type tester is designed to simply indicate how the tube or device under test compares with the manufacturer's standards. These standards are predetermined parameters and ratings that have been obtained by exacting laboratory methods. Although the field-type tester does not tell you that a tube or device necessarily functions as it should in a particular circuit, it does provide a quick way of finding a substandard tube or semiconductor. In this chapter, we discuss the circuits used in testers and the indications of various tests. So that you can better evaluate the readings obtained from field-type testers, we also point out some limitations of these instruments.

21. Electron Tube Testing

21-1. There are two different types of tube testers commonly used in the field. These testers, which are distinguished by the main tube characteristic they check, are known as the *emission tester* and the *transconductance tester*. Field-type tube testers may also be capable of performing short circuit, noise, gas, cathode leakage, and filament activity tests.

21-2. **Emmission Testers.** The emission-type tube tester indicates the condition of the cathode emitting surface. Usually, the end of the useful life of a tube is preceded by a reduction in emissivity; that is, the cathode becomes unable to supply the number of electrons necessary for proper tube operation. Also, if the tube has an open element, the defect prevents proper emission, and the tester indicates it as a weak or bad tube.

21-3. The emission-type tester has several disadvantages. Since the manufacturer of a tube does not state a definite 100-percent emission point which could be used for reference, the emission test is not conclusive. High emission does not necessarily indicate a good tube, because this condition might be present in a tube with a faulty grid structure or in one which has a highly emissive spot on its cathode; very high emission has also been observed just before a tube fails completely. Furthermore, low emission does not necessarily indicate in all cases that a tube is near its end-of-life point. Another disadvantage of the emission test is that gas may be liberated within the tube when AC test voltages are applied, unless the test is made quickly. Also, because the tube is not operated with its recommended DC electrode voltages in this test, it is not tested under actual operating conditions. Sometimes a tube will show normal emission and yet not operate properly. The reason for this is that the efficiency of a grid-controlled tube depends on the ability of the grid voltage to control the plate currect. The emission-type tester checks only the plate current developed and not the ability of the grid to control the plate current.

21-4. To check the emission of a grid-controlled tube (triode or multigrid types), the tube is connected as a half-wave rectifier, as shown in figure 106. The rated filament power is furnished by the tester. The plate and grids of the tube are connected. DC milliammeter M1 and variable resistor R1 are connected in series with the tube, and the entire circuit is connected in series with the tube, and the entire circuit is connected across a secondary of

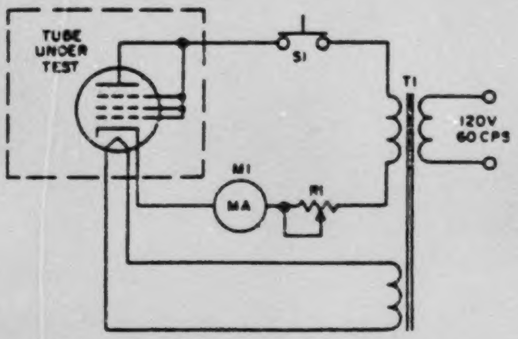


Figure 106. Emission test circuit.

transformer T1. Since the plate and grids are connected, the tube functions as a diode rectifier, conducting current only on the alternate half cycles when the plate and grids are positive with respect to the cathode. The amount of current that flows is an indication of the condition of the cathode emitting surface. On emission-type tube testers, the milliammeter scale is usually divided into three areas which are labeled *good, weak* and *bad*, or other similar designations. Thus, when using an emission-type tube tester, you will not determine the actual current flow through the tube, but only the general condition of the tube.

21-5. The emission test for diode detector and rectifier tubes and the diode portion of multisection tubes is similar to the emission test for grid-controlled tubes. The rated filament power is furnished by the tester, and an AC test signal is applied to the diode when switch S1 is closed. The amplitude of the test signal may be varied by the tapped secondary of transformer T1, and current through the tube can also be regulated by variable resistor R1. The amount of current flowing through the test circuit is measured by meter M1. The value of this current depends on the electron emission within the tube, and therefore, is an indication of the condition of the tube.

21-6. **Transconductance Testers.** The transconductance type of tester provides a more accurate evaluation of the condition of a grid-controlled tube than the emission-type tester, because it measures the amplification ability of the tube under simulated circuit conditions. The transconductance is measured and then compared with the ratings of the tube manufacturer. The meter scale of this type of tube tester may be calibrated to read the transconductance (Gm) in micromhos. Often the scale is divided into sections that indicate whether the tube is *good, weak*, or *bad*. A voltage or power- amplifier tube is considered defective when its transconductance decreases to 70 percent of the value stated in standard tube tables; the oscillator section of a converter tube is considered defective when its transconductance decreases to 60 percent of table values.

21-7. As you know, the term "transconductance" (also called *mutual conductance*) indicates the effect of the control grid voltage upon the plate circuit of a tube. This characteristic is expressed mathematically as the ratio of a change in plate current to a small change in control grid voltage, with all other electrode voltages held constant. The equation for transconductance is:

$$Gm = \frac{\Delta\ Ip}{\Delta\ Eg}$$

where Gm is the transconductance in micromhos, Δ Ip is the change in plate current in microamperes, and Δ Eg is the change in control grid voltage. When the control grid voltage changes 1 volt, the current change in microamperes is equal to the transconductance in microhms. Thus, if a 1-volt change in control grid voltage produces a 200-microampere change in plate current, the tube has a transconductance of 200 micromhos. The transconductance of a tube may be measured by two methods: one is the *static* (DC) method and the other is the *dynamic* (AC) method.

21-8. *Static method*. In the static (also called the *grid shift*) method of measuring transconductance, the DC bias voltage on the control grid of the tube under test is changed, and the resultant change in the steady plate current is measured with a DC milliammeter. The simplified circuit for this test is shown in figure 107. Filament voltage is furnished to the tube under test by the tube tester. When switch S1 is set at position 1, a negative bias voltage is applied to the control grid of the tube and the resultant plate current is measured by meter M1. Switch S1 is then set at position 2; the control grid bias becomes less negative and the plate current increases in value. Resistor R3 is adjusted so that current through the test circuit produces a known voltage drop across resistor R2. The transconductance can then be determined by the change of plate current divided by the voltage drop across resistor R2. To simplify testing, the meter scale can be divided into *good, weak*, and *bad* sections in the same manner as on many emission-type testers. When this type of circuit is used to test various types of tubes, the voltages applied to the electrodes must be made adjustable so that the correct operating conditions for a particular tube may by obtained.

21-9. *Dynamic method*. The dynamic method of determining transconductance makes use of a circuit which applies an AC test

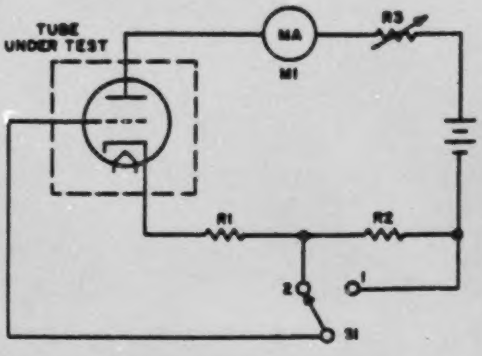


Figure 107. Transconductance static test circuit.

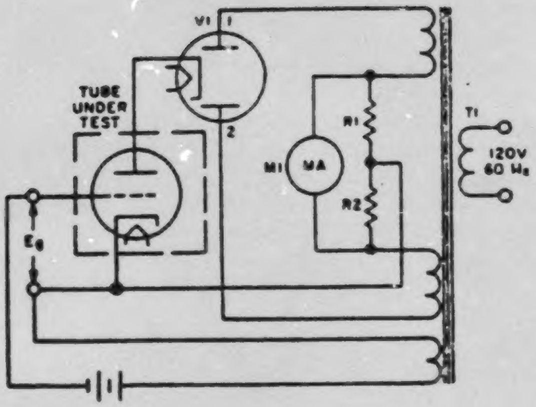


Figure 108. Transconductance dynamic test circuit.

signal and a DC bias voltage to the control grid of the tube under test. A simplified circuit for this test is shown in figure 108. The tube under test serves as the load for rectifier V1. With a fixed value of bias voltage (Eg) applied to the control grid of the tube under test, the circuit operates as a simple full-wave rectifier. On the half cycle of the AC voltage, when plate 1 of rectifier V1 is positive, there is current flow through resistor R1, and the force exerted on the pointer of meter M1 attempts to deflect the pointer in one direction. When plate 2 of rectifier V1 becomes positive, current flows through resistor R2, and the force exerted on the pointer of meter M1 is equal and opposite to the previous force. Since these alternations occur at a relatively rapid rate (60 times a second), the resultant force exerted on the meter pointer is zero; consequently, the meter pointer remains stationary in the ZERO position if there is a fixed DC bias.

21-10. In addition to the fixed DC bias voltage, an AC voltage from the secondary of transformer T1 is applied to the control grid of the tube under test. When this AC voltage becomes negative at the same time that plate 1 of V1 is positive, the plate current of the tube under test decreases for this half cycle. This current flows through resistor R1, decreasing the deflecting force on the meter pointer in one direction. When the AC voltage applied to the control grid becomes positive, this voltage increases the plate current of the tube under test. During this half cycle, plate 1 of V1 is positive and the current through R2 increases. As a result, the deflecting force on the meter pointer during this half cycle exceeds the force exerted during the previous half cycle. Hence, the meter deflection is undirectional and is proportional to the difference of the currents in R1 and R2 resulting from the application of the AC voltage to the grid of the tube under test Therfore, the meter indicates the change in plate current produced by a change in grid voltage under dynamic conditions. The meter can be calibrated in micromhos, or the meter scale can be divided into sections to indicate *good*, *weak*, or *bad*. Any pronounced deviation from the rated, or normal, transconductance for a specific tube indicates a defective tube.

21-11. **Additional Test Circuits.** Besides testing emission or transconductance, there are several other useful tests that can be made.

21-12. *Short-circuit and noise test.* It is very important that you apply the test for short-circuited elements to a tube of doubtful quality before any other tests are made. This procedure protects the meter (or any other indicator) from damage. Also, it follows logically that if a tube under test has elements which are short-circuited, there is no further need to apply additional tests to that tube. Short-circuit tests usually indicate leakage resistance less than about 1/4 megohm. The proper heater voltage is applied so that any tube elements which might short as a result of the heating process will be detected. The short-circuit test is similar to the test used to detect noisy (microphonic) or loose elements. Since the only difference between the two tests is in the sensitivity of the device used as an indicator, the noise test will be discussed as part of the short-circuit test.

21-13. Figure 109 shows a basic circuit used for detecting shorted elements within a tube. With the plate circuit switch set at position 2, as shown, the plate of the tube under test is connected to the leg of the transformer secondary containing the neon lamp. All other elements are connected through switches to the other leg of the secondary. If the plate element is shorted to any other element of the tube, the transformer secondary circuit is completed; as a result, both plates of the neon lamp glow since AC is applied to the lamp. If no short exists, no indication will be present (or only one plate of the neon lamp will glow because of rectification

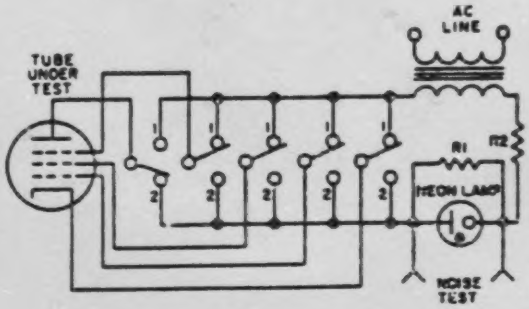


Figure 109. Short circuit and noise test circuit.

by the tube). Each of the other elements is tested by means of the switching arrangement shown. Resistor R2 limits the current through the neon lamp to a safe value. Resistor R1 bypasses any small alternating currents in the circuit which might be caused by stray capacitance and thus prevents the neon lamp from indicating erroneously. Tapping the tube lightly is recommended to detect loose elements which might touch when the tube is vibrated.

21-14. The noise test is, in effect, nothing more than a very sensitive short-circuit test. In figure 109, two leads are taken from the neon lamp (one lead from each side) and brought to external receptacles which are labeled *noise test*. An external amplifier and a speaker (not included with the equipment) are connected to these receptacles. Perhaps the handiest amplifier for this test is an ordinary radio receiver. The antenna and ground terminals of the receiver are connected to the noise-test jacks, and a normal short-circuit test is made while you are tapping the tube. If tube elements are loose (but perhaps not loose enough to indicate on the neon lamp), loud crashes of noise (or static) will be heard from the receiver over and above the amount of noise that is normally present. The noise test may also be made without the use of the high-gain amplifier, merely by inserting the leads from a pair of headphones into the noise-test receptacles. The latter check, of course, is not as sensitive as the test made with the amplifier but is generally more sensitive than the short-circuit test made with the neon lamp as an indicator.

21-15. *Gas test.* In all vacuum-type electron tubes, the presence of gas is undesirable. When gas is present, the electrons emitted by the cathode collide with the molecules of gas. These collisions cause electrons to be dislodged from the gas molecules, and positive gas ions are formed. These ions are attracted by (and cluster around) the negatively biased control grid of the tube. If the amount of gas in the tube is appreciable, the resulting flow of grid current is noticeably high. The basic circuit used for the gas test is shown in figure 110. With switch S set to position 1, a certain value of plate current is measured by the DC milliammeter. If there is no gas (or a negligible amount) present in the tube, throwing switch S to position 2 does not change the plate current reading. If gas is present, current flows through the grid resistor (large value), causing a voltage drop with the polarity as shown. The net effect is to reduce the negative bias voltage on the grid of the tube, resulting in an increase of plate current. Small plate current increases are normal; large increases indicate excessive gas.

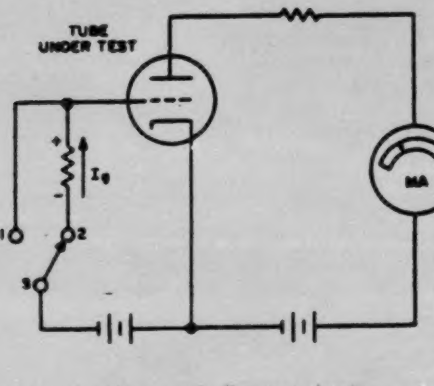


Figure 110. Gas test circuit.

21-16. *Cathode leakage test.* When a tube which uses an indirectly heated cathode develops noise, it is likely that a leakage path is present between the cathode sleeve and the heater wire. This is true because in the design of a tube the heater must be placed as close as possible to the cathode so that maximum tube efficiency is attained. Continual heating and cooling of the tube structure may cause small amounts of the insulation between the cathode and heater to become brittle or to deteriorate, leaving a high-resistance leakage path between these elements. Under extreme conditions, the insulation may shift enough to allow actual contact of the elements. Since the heater and cathode are seldom at the same potential, any form of leakage causes noise to develop in the tube. The cathode is normally maintained at a higher positive potential, because cathode bias is the most common type of bias used. The heater circuit is usually grounded to the chassis, either on one side of the filament supply or by a centertap arrangement. Therefore, if a resistance path is present, a leakage current may flow from the heater to the cathode. Thus, the cathode receives electrons. Assuming the existence of high-resistance leakage, the current flow from the heater to the cathode will vary with any vibration of the tube, because vibration will vary the amount of resistance. If the cathode and heater are completely shorted (zero ohms), it is impossible for the tube to develop any cathode bias.

21-17. Figure 111 shows a basic circuit which is used to detect leakage between the heater and cathode elements of a tube. With switch S set to position 2, a certain value of plate current flows. When switch S is thrown to position 1, the cathode becomes a floating element; if no leakage path is present, the plate current should fall to zero. If the elements are completely shorted, the plate current reading remains the same as the initial reading (switch S

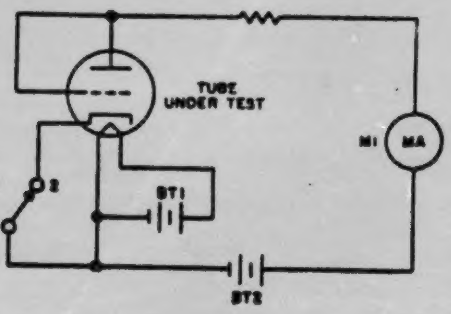


Figure 111. Cathode leakage test circuit.

in position 2); if they are only partially shorted, a plate current less than normal but greater than zero is indicated.

21-18. *Filament activity test.* The filament activity test is used to determine the approximate remaining life of an electron tube insofar as the longevity of the cathode emitter is concerned. The test is based on the principle that the cathode in almost all electron tubes is so constructed that a decrease of 10 percent of the rated filament or heater voltage causes no appreciable decrease in emission.

21-19. On tube testing equipment incorporating this test, there is a two-position switch (*filament activity test*), which has one position marked NORMAL and the other marked TEST. The switch remains in the NORMAL position for all the tests other than the filament activity test. When the switch is set to the TEST position, the filament (or heater) voltage applied to the tube under test is reduced by 10 percent.

21-20. The filament activity test is performed as follows: After the quality test is made, the TUBE TEST button is held depressed, and the FILAMENT ACTIVITY TEST switch is set to the TEST position. If the indicator shows a decreased reading after a reasonable time is allowed for the cathode to cool, the useful life of the tube is nearing its end.

21-21. A PRECAUTION: Before the tube to be tested is inserted in the correct test socket, be certain all front panel controls are set to the positions listed for that type of tube in the data chart furnished with the tester. This precaution is necessary to prevent excessive voltages from being applied to the tube elements (especially the filament).

22. Semiconductor Testing

22-1. Since semiconductor devices are extensively used in electronic equipments, it is important to know how these devices can be tested. We will cover the checks that indicate the condition and quality of crystal diodes and transistors in this section. Circuits with which these checks can be made are also presented to further your understanding of semiconductor testing.

22-2. **Diode Testers.** General-purpose germanium and silicon diodes can be checked with a static-type tester or a dynamic-type tester. Zener diodes are tested to determine how well and at what voltage they regulate.

22-3. *Static diode tester.* A common type of crystal diode tester is a combination ohmmeter-ammeter. Measurements of forward resistance, reverse resistance, and reverse current may be made with this instrument. The condition of the crystal rectifier under test can then be determined by comparison with typical values obtained from test information furnished with the tester or from the manufacturer's data sheets. The simplified circuit of a crystal diode tester is shown in figure 112. A check which provides a rough indication of the rectifying property of a diode is the ratio of the diode's reverse and forward resistance at a specified voltage.

22-4. *Dynamic diode tester.* To effectively test crystal diodes used for some special applications, it is necessary to obtain reverse resistance measurements for a large number of different voltage levels. This can be done efficiently by using a dynamic diode tester in conjunction with a cathode-ray oscilloscope to display the diode reverse-current-versus-voltage curve.

22-5. A simplified circuit of a diode dynamic tester is shown in figure 113. The test voltage from the input transformer is applied across resistor R4 and the parallel combination of resistor R5 and rectifier CR1. Crystal diode CR1 rectifies the voltage developed across resistor R5, and the resultant half-wave

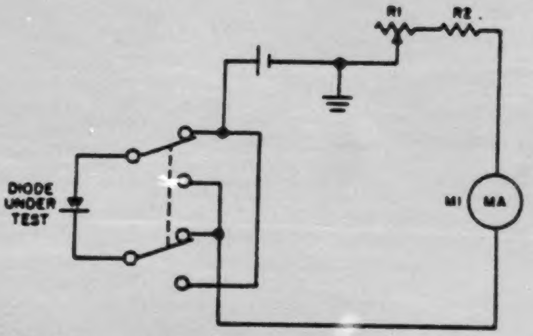


Figure 112. Semiconductor diode reverse-to-forward resistance test circuit.

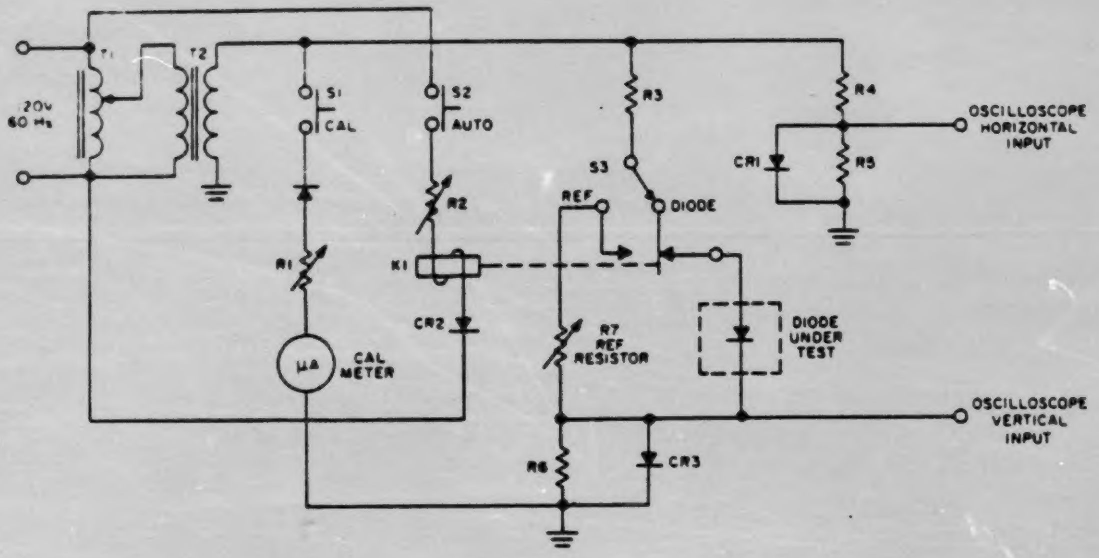


Figure 113. Semiconductor diode dynamic test circuit.

rectified voltage is applied to the horizontal input of an external oscilloscope. The amount of horizontal sweep of the associated oscilloscope is, therefore, proportional to the input voltage which is applied to the diode under test and the reference resistor.

22-6. The input test voltage is applied through resistor R3 to the moving arm of selector switch S3. With switch S3 in the REF position, a test current flows through internal reference resistor R7 and current measuring resistor R6. The internal reference resistor can be adjusted to equal the value of the minimum acceptable reverse resistance of the diode under test. A value of 500K may be typical for a new diode, and a value of 250K may be acceptable for the same type diode which has been in use. The signal developed across resistor R6 is applied to the vertical input of the external oscilloscope. Thus, the voltage drop across resistor R6 produces a vertical deflection of the oscilloscope trace which is proportional to the current through the test circuit. The action of crystal rectifier CR 3 causes this signal to be applied to the oscilloscope only during the same half cycle that the horizontal sweep voltage is applied. As a result, during each active half cycle, a diagonal straight line is displayed on the oscilloscope, as shown in figure 114,A. This pattern is the reference trace to which the characteristic curve of the diode under test can be compared.

22-7. When selector switch S3 is turned to the DIODE position, current flows through resistor R6. In this case, the voltage applied to the oscilloscope horizontal input remains the same, but the vertical input indicates instantaneous values of the reverse current in the test diode. This results in a curved line trace on the oscilloscope, as shown in fugure 114.B. This is the dynamic characteristic curve of reverse current versus voltage for the diode under test. When selector switch S3 is in the DIODE position and AUTO switch S2 is closed, the test current is applied alternately to the diode under test and to the reference resistor. This gives a display of both traces simultaneously on the oscilloscope. The switching operation is accomplished by relay K1. Voltage applied to this relay through switch S2 is rectified by CR2. Current flowing through the relay is controlled by resistor R2, which is adjusted so that the relay armature will vibrate and produce a minimum amount of joining of the diode and reference resistor traces. The vibration of the relay is rapid enough to create the illusion of a simultaneous display of the diode and reference resistor test current patterns on the associated oscilloscope (see fig. 114,C).

22-8. Trace calibration is done by closing S1. The input signal is rectified and the

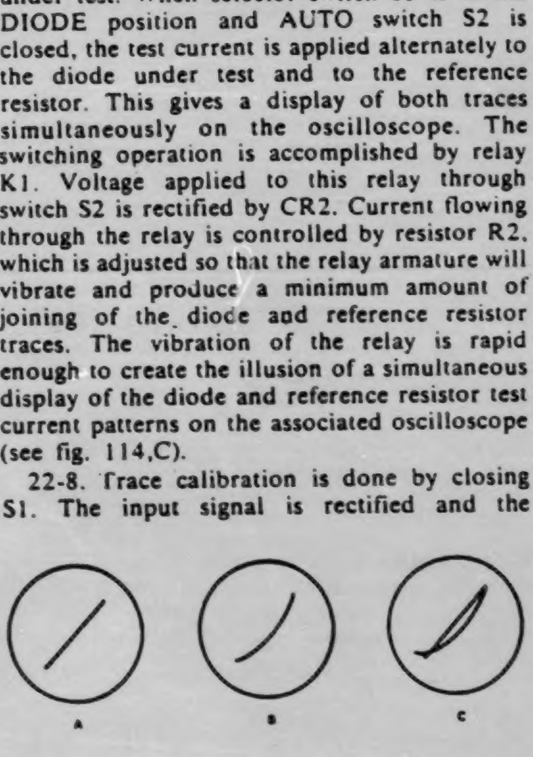


Figure 114. Semiconductor diode linearity test.

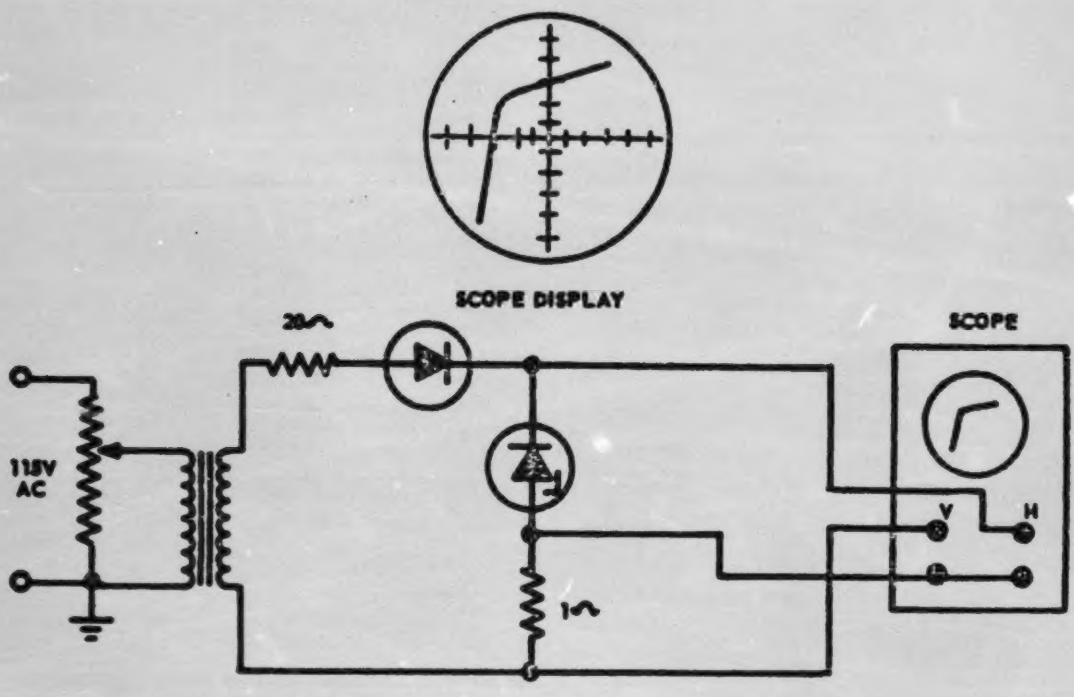


Figure 115. Zener diode I versus E test circuits.

pulsating direct current indiates the signal level on the DC microammeter. Adjustment of resistor R1 permits calibration of the meter to read the voltage developed across the secondary winding of transformer T2.

22-9. *Regulator diode tests.* Zener (avalanche) diodes, which are used for voltage-regulating applications, may be checked by the use of a dynamic tester in conjunction with an oscilloscope. This tester develops signals to display the diode reverse-current-versus-voltage curve on the associated oscilloscope, for determination of the diode's Zener voltage, dynamic impedance, and noise characteristic.

22-10. In figure 115, we show a simple circuit that can be used to obtain a dynamic characteristic curve of a Zener diode. The AC input is adjusted until the display shows the breakdown operation as illustrated on the scope screen of figure 115. The crystal diode blocks the negative alternation of the input, thereby preventing forward conduction of the Zener diode; thus, the trace shows only reverse current versus voltage. Note that the reverse-current signal is developed across the 1-ohm resistor and is applied to the vertical input terminals of the scope; the voltage across the Zener is applied to the horizontal input terminals of the scope. This makes the vertical axis of the scope represent current, and the horizontal axis represent voltage. If the axes are calibrated, the Zener breakdown voltage, Vz, and dynamic impedance, Zz, can be determined.

22-11. When you wish just to check the operating voltage of the Zener diode, the circuit shown in figure 116 can be used. Adjust the variable resistor to obtain the value of

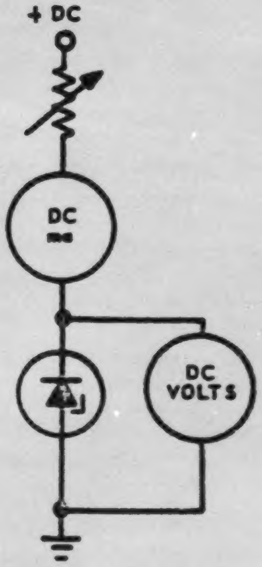


Figure 116. Zener voltage test circuit

operating current specified for the Zener diode under test. If the Zener diode is good, the reading on the DC voltmeter will conform closely to the rated operating voltage. For example, a 15-volt Zener diode under test should cause the voltmeter to indicate near 15 volts. The acceptable tolerance, of course, depends upon the application and is something you must know.

22-12. **Transistor Testers.** We will discuss transistor tests that are of practical value to a maintenance repairman. The basic circuits are illustrated so that you can understand the test for (1) collector leakage current, (2) punch-through voltage, (3) direct-current gain, and (4) hybrid parameters.

22-13. *Collector leakage current test.* As you know, the amount of collector leakage current is normally a very small value (about 10 microamps or less). The collector leakage current will be appreciable, however, when the transistor is contaminated, internally shorted, or damaged by overheating. A measurement of collector leakage current can, therefore, indicate the condition of a transistor.

22-14. Figure 117 shows the method of determining collector leakage current. When the transistor is connected as illustrated, the amount of collector-to-base leakage current, Ico, can be read directly on the DC microammeter. The reading should check closely with the manufacturer's value of Ico at the specified collector-to-base voltage, Vcb. This current is also referred to as *collector cutoff current* or *reverse current.*

22-15. *Punch-through voltage test.* The punch-through voltage (Vpt) is that Vcb at which the collector-base barrier region has widened sufficiently to contact the base-emitter barrier region. This effectively eliminates the base region; therefore, transistor action is stopped and collector-to-emitter resistance is greatly reduced. The punch-through voltage can be applied without damaging the transistor if the collector current is limited to prevent over-heating. When the collector-to-base voltage is lowered below the punch-through value, normal transistor action will resume.

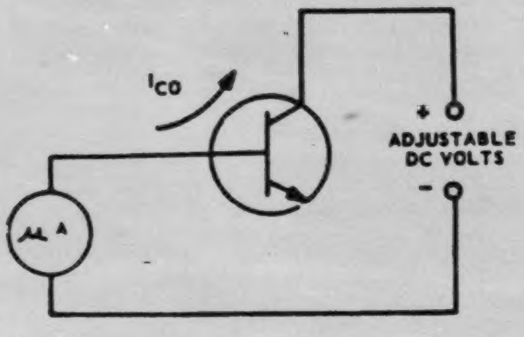


Figure 117. Collector leakage current test circuit.

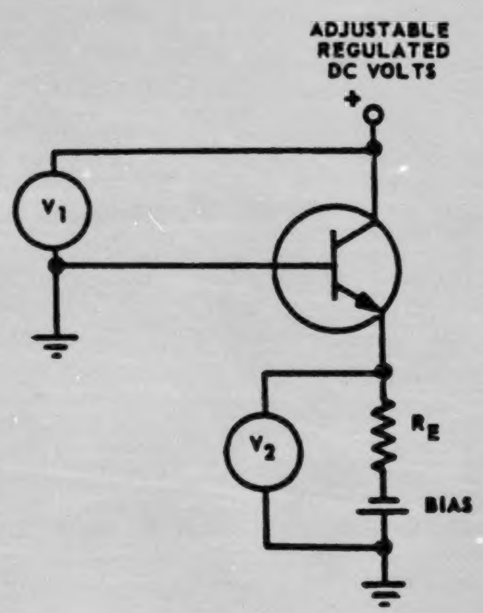


Figure 118. Punch-through test circuit.

22-16. The value of punch-through voltage is generally specified only for switching-type transistors. A circuit that can be used to check the Vpt of a transistor is shown in figure 118. The transistor is biased to its typical operating values; then the collector voltage is increased until voltmeter V2 shows a sudden increase. This increase is caused by the increased current flow through R_E when punch-through occurs. The reading of V1 is the punch-through voltage of the transistor under test.

22-17. *Direct-current gain test.* The ratio of the output direct curent to the input direct current indicates the direct-current gain of a transistor. This parameter is useful when a transistor is used in a low-frequency power amplifier, switching control, and logic circuits. If the direct-current gain decreases with age, the reduced amplification can produce distortion and changes in impedance which cause mismatching.

22-18. Direct-current gain is commonly specified for the CE configuration and is designated β or h_{fe}. This parameter, β, is equal to the direct-current ratio I_c/I_b. A method of determining this ratio for PNP transistors is shown in figure 119. After adjusting for proper biases, the milliammeters are read to obtain the values of I_c and I_b. NPN transistors can be tested simply by reversing the polarity of the

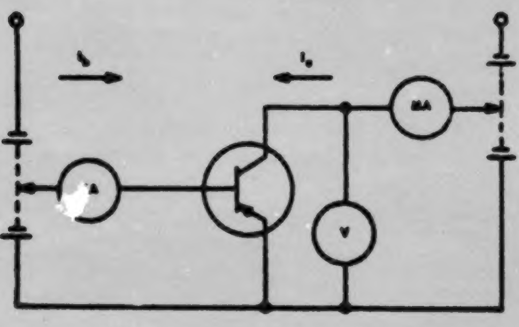


Figure 119. Direct-current gain test circuit.

bias supplies and reversing the meter connections.

22-19. Another test circuit uses a null detector as shown in figure 120. This circuit is biased for an NPN transistor. Biases must be adjusted to the specified values for the transistor under test. The differences of the voltages V1 and V2 are indicated on the null detector. By adjusting the potentiometer, voltage V1 is made equal to V2, and the null indicator reads zero. Hence,

$$\beta = \frac{I_c}{I_b} = \frac{V2/R2}{V1/R1} = \frac{R1}{R2} \qquad \text{when } V1 = V2$$

22-20. Note that there is linear relation between current gain and R1 since R2 is fixed value. It is, therefore, possible to calculate a dial on the potentiometer to read β directly. The maximum β that can be measured will, of course, be the maximum ration R1/R2 obtainable with the tester

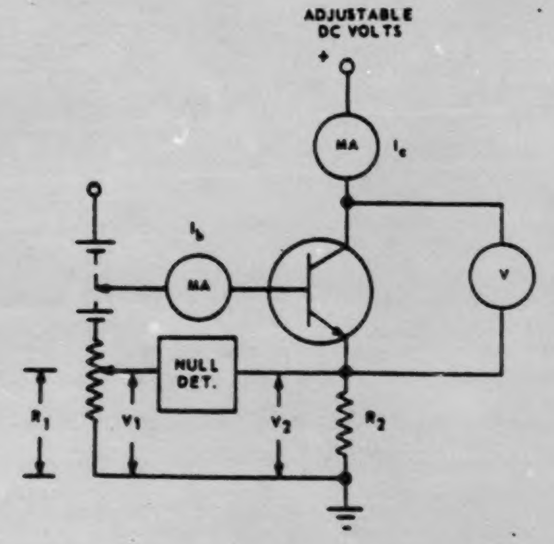


Figure 120. Null detector direct-current gain test circuit.

22-21. When testing for direct-current gain, you should disconnect the transistor from its circuit. Any associated circuit that shunts the transistor will introduce error.

22-22. *Hybrid parameter tests.* When a transistor is considered to be four-terminal network (see fig. 121), various relations between input and output voltages and currents can be defined in terms of AC parameters. These are known as *small-signal parameters* that indicate the performance capabilities and characteristics of a transistor.

22-23. Most manufacturers' transistor data sheets specify hybrid (h) parameters; h_i is the input impedance in ohms with the output shorted (fig 122,A); h_r is the reverse voltage gain, or ratio of V1 to V2, with the input open circuited (fig. 122,B); h_f is the forward current gain, or ratio of i2 to i1, with the output shorted (fig. 122,C); and h_o is the output admittance in mhos with the input open circuited (fig. 122,D). To indicate whether the parameter is for the common base, common emitter, or common collector transistor circuit, an additional subscript (b, e, or c) is added to the h parameter. For example, the common base forward current gain, which is the same as α, is designated h_{fb}; and the common emitter forward current gain, which is the same as β, is designated h_{fe}.

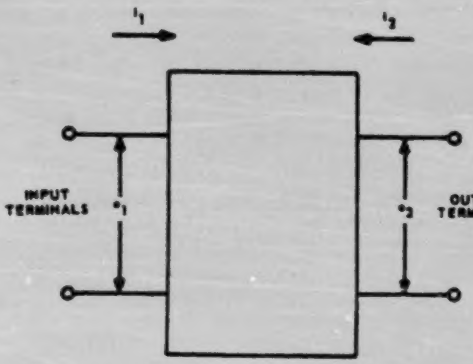


Figure 121. Four-terminal network.

22-24. Since we know that α and β are related by the following equations,

$$\alpha = \frac{\beta}{1 + \beta} \text{ and } \beta = \frac{\alpha}{1 - \alpha}$$

it follows that

$$h_{fb} = \frac{h_{fe}}{1 + h_{fe}} \text{ and } h_{fe} = \frac{h_{fb}}{1 - h_{fb}}$$

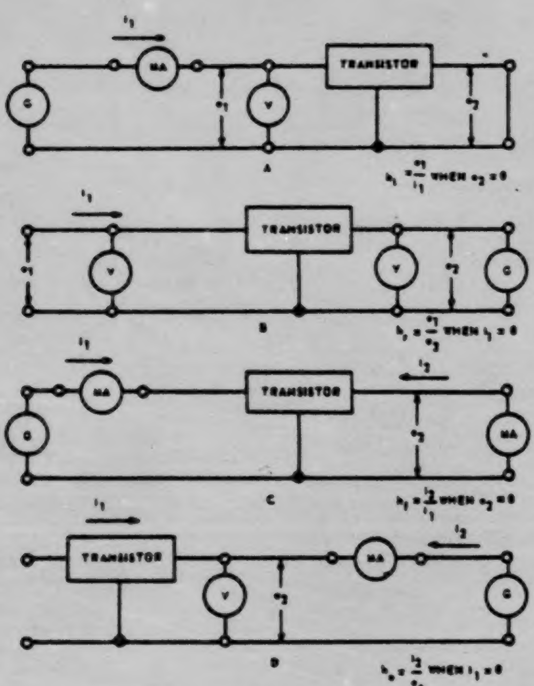

i_1
MA
TRANSISTOR
G
V
e_1
e_2
A
$h_i = \frac{e_1}{i_1}$ WHEN $e_2 = 0$
i_1
TRANSISTOR
V
V
G
e_1
e_2
B
$h_r = \frac{e_1}{e_2}$ WHEN $i_1 = 0$
i_1
MA
TRANSISTOR
i_2
G
MA
e_2
C
$h_f = \frac{i_2}{i_1}$ WHEN $e_2 = 0$
i_1
TRANSISTOR
MA
i_2
V
G
e_2
D
$h_o = \frac{i_2}{e_2}$ WHEN $i_1 = 0$

Figure 122. Hybrid parameter equivalent circuits.

Thus, regardless of how current gain of a transistor is specified, you can determine its gain capability. Values of h_{fb} usually range from 0.95 to 0.99; values of h_{fe} range from about 20 to 100. Hybrid parameters are generally specified as shown in figure 123.

22-25. A basic transistor test set for measuring *h* parameters is shown in figure 124. A single AC meter, M, calibrated to read voltage and current values, is used in conjunction with calibrated voltage source, G2, and current signal source, G1, to determine the four hybrid parameters of a common base transistor configuration. The magnitude of the output from the voltage and current signal sources is controlled by range switches, which are not shown in this basic circuit diagram. The parameter to be measured is chosen by a single selector (four ganged switches), which also connects the proper bias. Since the emitter bias supply has an internal dynamic resistance of approximately 10 megohms, it may be considered an open circuit for AC.

22-26. Let us consider each position of the selector to see how each parameter is determined.

a. Position 1. The calibrated voltage generator, G2, applies e2 to the collector, and the meter reads the circuit current 12 (the resistor R1 develops the signal that is measured by the meter M). Since the emitter is open-circuited for AC, the value of h_{ob} is the ratio e2/12.

b. Position 2. Note that meter M is now connected between the emitter and ground and, therefore, reads the voltage e1. The calibrated generator G2 applies e2 to the collector. The ratio e1/e2 is the value of h_{rb}.

c. Position 3. The calibrated current generator, G1, is connected to the emitter. This means the value of i1 is known. The meter M now reads the input voltage e1. Because the output circuit is virtually short-circuited (R2 is a small resistor), the value of h_i is the ratio of i1/e1.

d. Position 4. The calibrated current generator is connected to the emitter; thus i1 is known. The meter M in conjunction with shunt

PARAMETER	MINIMUM	VALUE DESIGN CENTER	MAXIMUM	DIMENSION
h_{ob}	0.1	0.8	1.5	μ mhos
h_{fe} (β)	30	42	66	none
h_{ib}	25	29	35	ohms
h_{rb}	0.1×10^{-3}	0.5×10^{-3}	1.5×10^{-3}	none

Figure 123. Example of hybrid parameter values.

SELECTOR POSITION	PARAMETER
1	h_{ob}
2	h_{rb}
3	h_{ib}
4	h_{fb}

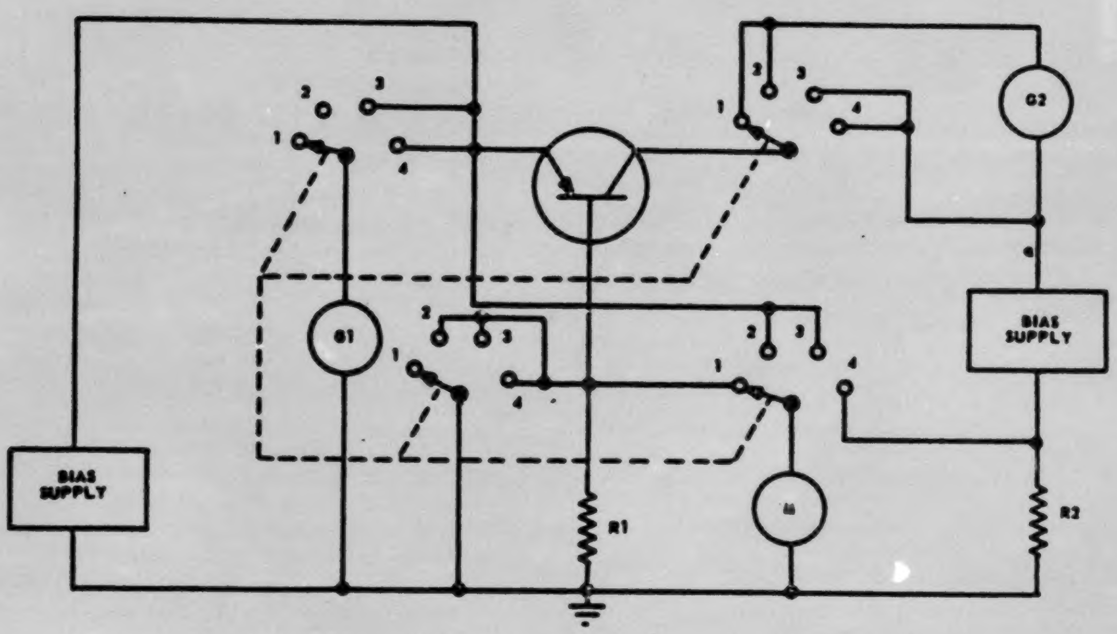


Figure 124. Hybrid parameter test circuit.

R2 reads the collector current, which is i2. The ratio i2/i1 gives us the value of h_{fb}.

22-27. The tester we have just discussed is, of course, a very simple one. Transistor testers for general use in the field are more complex since they are designed for both in-circuit and out-of-circuit testing. Moreover, they provide for short-circuit tests, bias selection, beta measurement, and collector reverse-current tests. In other words, a practical transistor tester generally incorporates all circuits that we have discussed separately, plus other testing features.

22-28. At this time, work the chapter review exercises for Chapter 6 in your workbook.

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ECI Form No. 17

STUDY REFERENCE GUIDE

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2. *Use the Guide for Follow-up after you complete the Course Examination.* The CE results will be sent to you on a postcard, which will indicate "Satisfactory" or "Unsatisfactory" completion. The card will list *Guide Numbers* relating to the items missed. Locate these numbers in the Guide and draw a line under the Guide Number, topic, and reference. Review these areas to insure your mastery of the course.

Guide Number

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CHAPTER REVIEW EXERCISES

The following exercises are study aids. Write your answers in pencil in the space provided after each exercise. Immediately after completing each set of exercises, check your responses against the answers for that set. Do not submit your answers to ECI for grading.

CHAPTER 1

Objective: To demonstrate a knowledge of supervision principles and the types of training programs available to the airman, whether formal, informal, correspondence, on base, or off base.

1. What is a supervisor? (1-2)

2. With the assignment of responsibility, what else is due to the supervisor? (1-4)

3. Where does a supervisor's primary responsibility lie? (1-6)

4. How demanding are the responsibilities of a supervisor to himself? (1-9)

5. In solving an employee relations problem, what steps should you use? (1-12)

6. Must all workers be told how, when, and what to do in work assignment? (1-14-16)

7. Give two reasons for a thorough examination of a completed repair job on a piece of equipment. (1-18)

8. How can you measure a worker or group of workers as to performance? (1-22,23)

9. Why is the performance report so important? (1-25)

10. You have successfully arrived at the 7 level in your chosen career field. How can you qualify for the 9 level (superintendent)? (2-5)

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11. What is lateral training? (2-6)

12. Formal airman courses are identified by the AFSC, by title, and by letter prefixes and suffixes, as needed. What does the first letter in the prefix tell you? (2-8)

13. What are the two divisions of on-the-job training? (2-10)

14. What is the meaning of the term "career development"? (2-11)

15. In which phase of the Dual-Channel Concept would you make the greatest progress in perfecting the skills in your chosen field? (2-12,13)

16. What must you do in order to receive the award of the 5 or 7 skill level of your AFSC? (2-15)

17. Why is the AF Form 623, Consolidated Training Record, so important to the airman? (2-21)

18. What training publication lists the knowledge required of a person on a certain job task? (2-25)

19. In what three ways is the Field Training Program conducted? (2-30)

20. Suppose that the Air Force has a surplus of airmen qualified in a certain AFSC. What is its most likely course of action? (2-34)

CHAPTER 2

Objective. To demonstrate a knowledge of the principles and objectives of ground safety applicable to the communications-electronics repairman's job.

1. What is the objective of safety education? (Intro.-1-4)

2. How can a start be made on good housekeeping? (3-2)

3. How does a cluttered workbench affect your work? (3-4)

4. What is the basic ingredient of all accidents? (3-10)

5. While accidents involving Air Force people and property can be described in terms of money costs, what is the most dangerous effect they can have? (3-16)

6. What must you have before an organized accident prevention effort can be successful? (3-18)

7. What is the best method for the prevention of fires? (3-20,21)

8. Which type of fire extinguisher would you use to extinguish a gasoline fire? (3-24; Fig 2)

9. How can you know that you are in an area contaminated by radioactivity? (3-27)

10. What kind of accidents should be reported? (3-29)

11. You don't live many years before you meet two types of common emergencies. What are they? (4-2)

12. What are the three life-saver steps in the treatment of a serious cut or wound? (4-4)

13. Name three ways to stop bleeding. (4-5-8)

14. What should you always treat an accident victim for, whether or not he has the symptoms? (4-11)

15. What are the symptoms of shock? (4-12)

16. What is artificial respiration? (4-15)

17. Although there are four methods of artificial respiration, why is the mouth-to-mouth method the most effective? (4-18)

18. What are the seven steps for administering mouth-to-mouth artificial respiration? (4-20)

19. What are the indications that the victim is responding to artificial respiration? (4-24)

20. What can you do to reduce the off-base, off-duty, privately owned vehicle accident rate? (5-5)

21. What good authority is available on sports safety? (5-8)

22. Why is life in the barracks subject to accidental injuries and deaths? (5-9-11)

23. List the safety items that every hobby shop user should be familiar with. (5-13)

CHAPTER 3

Objective: To demonstrate a knowledge of maintenance principles, printed card repair, man-hour reporting, maintenance data collection system, organizational structure, Chief of Maintenance functions, product improvement program, and the scope and application of technical order systems.

1. During what type of maintenance procedures are you likely to detect circuits which are in marginal condition? (6-2)

2. What would you look for when making a visual inspection of resistors and capacitors? (6-5)

3. What is the primary consideration when using solvents? (6-9)

4. What is the purpose of climatic deterioration prevention? (6-12)

5. In what TM can you find resistance measurements? (7-7)

6. What is the first precaution you must observe before making a resistance check? (7-7)

7. Name some uses of SWR measurements? (7-16)

8. In what direction are the bottoms of tube sockets counted? (7-23)

9. Where would you find the normal voltage and resistance values at the pins of connectors and tube sockets? (7-25)

10. List some things that you should include in your method of troubleshooting? (7-28,29)

11. Refer to figure 19 in the text. Using the half-split method, where would you check if there is no output from stage 8 and a check shows no output at point D? (7-34)

12. Why is it necessary to try to replace a defective component with one of identical characteristics and physical size? (7-42)

13. At what point in the corrective maintenance procedures would you normally align a circuit? (7-46)

14. What is determined by a performance test? (7-47)

15. Why is it necessary to handle printed circuits with care? (8-5)

16. What type of solder do you use to repair printed circuits? (8-11)

17. Name four types of wire wraps that you may be required to make? (8-19-23)

18. What is the smallest radius that you can bend a coaxial cable? (9-6)

19. What does a red printed identification code on a line signify? (9-7)

20. At what point on a ground wire 6 inches long would the wire identification code be printed? (9-7)

21. When should you use the single-wire safety method? (9-9)

22. Why is it necessary that bonding and grounding connections be properly made? (9-10)

MODIFICATIONS

Page 8 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

CHAPTER 4

Objectives: To demonstrate a knowledge of the components of an oscilloscope and how they operate, and to show ability to operate a sample synchroscope by analyzing presentations under given operating conditions.

1. List the basic circuits that make up an oscilloscope. (12-1)

2. Name four of the five special features usually found on a synchroscope. (12-1)

3. What are the functions of the anodes in a cathode-ray tube? (12-3)

4. How is the deflection sensitivity of an oscilloscope usually expressed? (12-6)

5. If 150 VDC causes a 3-inch displacement of the spot on the face of an oscilloscope, what is the deflection factor? (12-7)

6. What is generally used as the screen coating on a general purpose CRT? (12-10)

7. What happens to the electron beam if the lead connecting the aquadag to the power supply is open? (12-12)

8. What type of rectifier is normally used in the high-voltage power supply of an oscilloscope? (12-15)

9. What type of rectifier is normally used in the low-voltage power supply of an oscilloscope? (12-16)

10. What type of gas tube is used for sweep generators? (12-23)

11. Why must an oscilloscope sweep be linear? (12-27)

12. How is a stationary display obtained? (12-28,29)

13. What is the distinguishing feature of a synchroscope? (12-31,32)

14. If the sweep calibrator is set for 10 μsec/inch and the signal under test makes a complete cycle in 4 inches, what is the signal frequency? (12-35)

15. What is the purpose of a voltage calibrator on an oscilloscope? (12-42,43)

16. What is the purpose of retrace blanking? (12-46,50)

17. After you have adjusted the intensity control, what other control may you have to adjust? (13-4)

18. When a halo appears around the spot on an oscilloscope screen, what control should you adjust? (13-5)

19. When the spot is elliptical on the screen, what control should you adjust? (13-7)

20. What happens if you increase the gain control too much? (13-10)

21. What height-to-width ratio provides optimum display proportions for general purpose waveform examinations? (13-12)

22. What controls do you use to center the spot on the screen? (13-14)

23. If a stable display of 2½ cycles for a 1-kHz signal appears on a scope, what is the sweep frequency? (13-23)

24. What happens if you advance the synchronizing control too far? (13-32,33)

25. What is the purpose of the Z-axis in an oscilloscope? (13-35,36)

26. List precautions that you should take when using an oscilloscope to protect yourself and the equipment. (13-42,44)

27. What indication do you get when there is poor contact between the rotor and the resistive element in the vertical gain potentiometer? (13-50)

28. When operating the Tektronix 585A (fig. 65) in the "B" INTENSIFIED BY "A" sweep function, unblanking is a function of which sweep unblanking pulse and intensification is a function of which sweep unblanking pulse? (14-26-31)

29. Name the oscilloscope control that performs each function listed below.

    a. Determines input voltage required to deflect beam 1 cm vertically.
    b. Sets voltage level required to trigger the trigger generator.
    c. Positions intensified area of display.
    d. Selects desired sweep and unblanking signals.
    e. Adjusts trigger generator input circuits.
    f. Adjusts slope of sweep sawtooth.
    g. Selects sync signal slope that is to trigger the trigger generator.
    h. Selects dual or single vertical input functions.
    (Sec. 14, all paras.)

30. For best results, which triggering should you always use when checking phase relationships with the dual-trace oscilloscope plug-in adapter? (14-51)

31. What type of meter has a valid multiplying factor for all ranges when a high-voltage probe is used? (15-4)

32. List two purposes of a high-voltage resistive probe. (15-4,5)

33. If the small capacitor of a high-voltage capacitive probe is 5 $\mu\mu$f and the step-down ratio is 50, what is the value of the other capacitor? (15-8,9)

CHAPTER 5

Objective: To demonstrate a knowledge of the circuits used to check power and frequency.

1. What power does an ordinary AC wattmeter measure? (16-2)

2. What is the purpose of the compensating coils used in wattmeters? (16-4)

3. Wattmeters are usually limited to approximately how much current? (16-5)

4. What would you use to extend the range of a wattmeter to measure high AC power? (16-5)

5. Why does the accuracy of a wattmeter decrease when it is used to measure power above 1 kHz? (16-7)

6. What is the standard reference level for dbm? (16-12)

7. What type of meter would you use to check the input power to a transmitter? (16-13)

8. What measurement is the equivalent to 1 vu? (16-13)

9. In what power-measuring instrument is a thermistor commonly used? (16-14)

10. What power-measuring instrument uses an ultra-thin wire to measure power at microwave frequencies? (16-14)

11. What instrument would you use to get the most accurate measurement of high power? (16-16)

12. What fluid is normally used in flow caloriumeters that measure power at 1000 MHz and higher? (16-18–20)

13. List four types of frequency test instruments. (17-1)

14. What type of wavemeter is more suitable for measuring the frequency of low-power equipment? (17-2)

15. You want to check the approximate frequency of a tuned circuit before applying power. What type of meter would you use? (17-7)

16. What type of frequency meter uses a VFO for its internally generated frequency? (17-9)

17. What indication do you get when the frequency of the set under test and the frequency of the VFO of the heterodyne frequency meter are equal? (17-9)

18. What must you use with a heterodyne frequency meter when measuring frequencies at crystal checkpoints? (17-20)

19. What circuit is used in the input section of a frequency count to shape the output pulse? (18-4,5)

20. What section of the frequency counter contains the decade frequency dividers? (18-10)

21. What is the purpose of the read pulse in the frequency counter? (18-17)

22. What section provides the input to the input section of the frequency counter? (18-20)

23. If the gate-time selector switch of a frequency counter is set on 0.1 second and its readout is 47302, what is the frequency of the signal under test and the accuracy of the reading? (18-27)

24. How can you increase the accuracy of a frequency counter when measuring a high frequency? (18-27)

25. What happens to the accuracy of a frequency meter at lower frequencies? (18-28)

26. List three major sections usually found in a signal generator. (19-1)

27. What type of oscillator is commonly used in a signal generator above 300 MHz? (19-4)

28. You have a bench mockup with an oscilloscope installed as part of the test harness. Who has the responsibility for repair of this oscilloscope? (20-4)

29. What technical order do you refer to if you are in doubt as to the responsibility of calibrating a certain piece of test equipment? (20-5)

CHAPTER 6

Objective: To demonstrate a knowledge of the circuits used to test vacuum tubes and transistors.

1. State three disadvantages of an emission-type tube tester. (21-3)

2. The transconductance of an amplifier tube should be at least what percent of its rated value to be considered acceptable? (21-6)

3. Concerning transconductance, (a) what is it and (b) what does it indicate? (21-7)

4. What method of measuring transconductance is being used when DC bias is held constant and an AC test signal is applied to the grid of the tube under test? (21-9)

5. To protect the tester meter from damage, what test should you perform first on a tube? (21-12)

6. What tube check is a very sensitive short-circuit test? (21-14)

7. What are the symptoms of a tube with cathode leakage? (21-16)

8. A tube is considered substandard if a noticeable decrease in emission occurs during a filament activity test. What percent of the rated value must the emission decrease to indicate substandard operation? (21-18)

9. What indicates the rectifying ability of a crystal diode? (22-3)

10. When using the dynamic diode tester in figure 113, what curve is displayed on a scope to analyze the behavior of a crystal diode? (22-4)

11. A Zener diode regulates at approximately what voltage? (22-10)

12. How is collector leakage or cutoff current designated? (22-14)

13. What hybrid values correspond to alpha and beta for a transistor? (22-23)

14. If h_{fb} is 0.96, what is the value of h_{fe}? (22-24)

15. If h_{fe} is 50, what is the value of h_{fb}? (22-24)

ANSWERS FOR CHAPTER REVIEW EXERCISES

CHAPTER 1

1. A supervisor is a person who directs the efforts of one or more people in getting a job done.

2. Adequate authority must go hand in hand with the assignment of a responsibility. Under most circumstances, workers would doubt the wisdom of a supervisor who has been given inadequate or no authority on the job.

3. A supervisor's primary responsibility is always to the mission. Other considerations may be important, but are secondary.

4. Using a checklist as a guide, the supervisor must understand his organization, plan and get the work out, determine performance requirements, train workers, and work at self-improvement.

5. The following steps are the best in solving a problem: (1) get the facts; (2) weigh and decide; (3) take action, and (4) check results.

6. While some workers know what to do without being told, others will resent the supervisor who does not specifically lay out each detail. Then there are some who want instructions and cheerfully carry them out. No matter the type of workers, the supervisor must be sure that all know their duties.

7. A thorough examination of a job will (1) reveal whether the equipment will operate successfully and safely and (2) afford an opportunity to review with the worker the steps he has taken. This review can be used as a teaching device.

8. The Specialty Training Standard is your guideline so far as the skills and knowledges of a job are concerned. In many cases, you have to devise your own standards of measurement for workers against workers.

9. The performance report is the primary source for information on training, assignments, special actions, and promotion.

10. By experience on the job, a passing score on the USAF Supervisory Test, and a recommendation from your supervisor.

11. Lateral training is qualifying as a 5 level in a specialty other than your own before qualifying for the 7 level.

12. The first letter in the prefix tells you whether it is for airmen or officers–A for airmen and 0 for officer courses.

13. Career development and job proficiency development.

14. Career development is the acquiring of the background knowledge and specific information needed to be able to perform the duties of the AFSC in question.

15. Your greatest progress in perfecting your skills would be on-the-job training under the applicable Job Proficiency Guide.

16. Be certified by your supervisor, and serve a stipulated period in OJT status.

17. The AF Form 623 is the only *complete* record of training.

18. The specific Specialty Standard defines the task knowledge levels.

19. By field training detachments permanently assigned to a unit, by mobile training detachments, or by traveling teams.

20. The airmen will be given on-the-job training into a related AFSC in which there is a shortage.

CHAPTER 2

1. The more you know about the potential hazards of your job and off-duty activities, the better your chances for an accident-free life. You must periodically expose yourself to instruction in safe procedures for your own sake as well as for others.

2. By acquiring the habit of personal cleanliness and neatness, you will automatically extend the same habits to your work area.

3. A cluttered workbench makes effective work almost impossible and is the starting place for an accident.

4. The basic ingredient of all accidents is the law of cause and effect.

5. The missions of the Air Force may fail through accidents to people and equipment. This is the most dangerous effect.

6. You must have effective enforcement because accidents are frequently the direct result of violation of safety principles.

7. Good housekeeping prevents fires. Overloaded electric circuits, accumulation of oily wastes and rags, careless handling and storage of flammable or explosive material—all add up to poor housekeeping and become fertile causes of fires.

8. A foam-type extinguisher would be used on gasoline fires.

9. Where AFTO 9 series forms are displayed.

10. Report all accidents resulting injury or property damage.

11. Wounds or cuts and drownings are emergencies most of us face.

12. In treating a serious cut or wound (1) stop the bleeding, (2) prevent or treat shock, (3) protect the wound.

13. When trying to stop bleeding (1) apply a bandage and pressure directly to the cut, (2) apply hand or finger pressure at various points on a patient's body, and (3) apply a tourniquet (a tourniquet should be used only for source, life-threatening hemmorrhaging that cannot be controlled by other means).

14. You should always treat an accident victim for shock.

15. The symptoms of shock are: (a) trembling and apparent nervousness; (b) rapid and weak pulse; (c) excessive thirst; (d) becoming quite pale and perspiring; (e) gasping for air and even fainting; and (f) vomiting or complaining of nausea.

16. Artificial respiration is a means of causing air to flow in and out of the lungs of a person when his normal breathing system ceases to function.

17. Mouth-to-mouth artificial respiration can be used even though the victim has suffered serious fractures, burns, or other injuries. It is also the surest method of getting oxygen into the lungs.

18. (1) Turn the victim on his back; (2) clean the mouth, nose, and throat; (3) place victim's head in the "sword swallowing position"; (4) hold the lower jaw up; (5) close the victim's nose; (6) blow air into the victim's lungs; and (7) let air out of victim's lungs.

19. The first indications of the victim responding to artificial respiration will be a gurgling or gasping for air and possibly coughing and gagging.

20. Learn the traffic laws that are in effect in your location and observe these laws strictly.

21. The Air Force Sports Manual, AFM 215-2, is an authority on sports safety.

22. Barracks life, like home life, can produce many accidents. Carelessness and horseplay are common causes.

23. (a) Make sure you are well oriented on the use of the equipment; (b) use safety guards at all times; (c) make sure that the floor around machines is free from stumbling and tripping hazards, and (d) keep the floor clear of sawdust and scraps.

CHAPTER 3

1. Preventive maintenance procedures are designed to detect conditions that may lead to malfunctions. This includes marginal operations.

2. Resistors and capacitors that are discolored, burnt, or cracked.

3. Adequate ventilation.

4. To prevent arcing, frequency shift, short circuits, and general deterioration due to excessive humidity, condensation, and the resultant growth of fungi.

5. The maintenance manual for the particular piece of equipment on which you are working.

6. Remove power from the circuit under test.

7. To indicate a poor or good impedance match, in making repairs, for preventive maintenance, and in checking and making adjustments to transmitters.

8. Clockwise.

9. In the voltage and resistance charts in your equipment technical orders.

10. Examination of all available equipment records, evaluation of operator's comments, and performance of operational checks when possible.

11. Point B.

12. Because in high-frequency circuits, the different characteristics may cause the circuit frequency to change.

13. After all repairs have been corrected, and only then if it is absolutely necessary.

14. The operating efficiency of the equipment.

15. Because the materials used are very fragile.

16. 60/40 solder.

17. Eyelet terminal wire, terminal wire, old lead, and new component wraps.

18. Six times the diameter of the coaxial cable.

19. That it is an AC line.

20. Near the center.

21. For emergency devices, for areas difficult to reach, and on small screws in a closely spaced pattern.

22. Bonding and grounding connections must be made properly to protect equipment and personnel from lightning discharges and electrical shock, to prevent development of RF potentials, and to provide current return paths.

CHAPTER 4

1. Cathode-ray tube, sweep generator, horizontal and vertical deflection amplifiers, and power supplies.
2. Triggered sweep, retrace blanking, marker generator, and voltage calibrator.
3. The anodes accelerate the electrons and focus the beam.
4. In millimeters per DC volt.

5. $\frac{150\text{ VDC}}{3\text{ in.}} = 50$ VDC per inch.

6. Green phosphor.

7. It disperses and illuminates the screen.

8. Because the current required to operate a CRT is very small, a half-wave rectifier is normally used.

9. Full-wave. The current required is moderate.

10. Thyratron.

11. To prevent distortion of the displayed signal.

12. By synchronizing the sweep generator with the incoming signal.

13. The sweep of a synchroscope is triggered.

14. $\frac{1}{4 \times 10\ \mu\text{sec}} = \frac{10^6}{40} = 25$ kHz.

15. To enable you to use the oscilloscope as a voltmeter.

16. To keep the electron beam from being seen during fly-back time.

17. The focus control.

18. The intensity control.

19. The focus control.

20. The vertical amplifier is overdriven and the display is distorted.

21. A height-to-width ratio of 2:3 or 4:5 is optimum. These ratios usually assure that a true representation of the wave is displayed.

22. The vertical and horizontal positioning controls.

23. $\frac{1000}{2.5} = 400$ Hz.

24. The sweep generator operates erratically and the display is distorted.

25. For intensity modulation of the electron beam by the input signal.

26. Do not operate an oscilloscope when its case is removed and be sure the oscilloscope is properly grounded. Handle a CRT carefully, do not allow a bright spot to remain stationary on a CRT screen.

27. Grass on the display.

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28. B, A.

29. *a.* Volts/cm.
    b. Triggering level.
    c. Delay-time multiplier.
    d. Horizontal display.
    e. Triggering source.
    f. Time/cm.
    g. Trigger slope.
    h. Mode.

30. The external signal. This keeps each signal from triggering its own sweep.

31. VTVM.

32. It decreases the effect of boltmeter loading and provides isolation.

33. $C_2 = 5\,(50 - 1)\ \mu\mu f = 245\ \mu\mu f$.

CHAPTER 5

1. Real or in-phase.

2. To insure a zero reading with no load.

3. 20 amperes.

4. A current transformer.

5. The accuracy decreases because at high frequencies magnetic fields affect the meter.

6. 1 milliwatt.

7. A vu meter.

8. 1 dbm.

9. Bolometer.

10. Bolometer.

11. Calorimeter.

12. Water is used at frequencies above 1000 MHz because of its excellent thermal qualities.

13. Wavemeter, grid-dip meter, heterodyne frequency meter, and frequency counter.

14. Reaction type.

15. Grid-dip meter.

16. Heterodyne frequency meter.

17. The best frequency is zero.

18. Calibration book.

19. Schmitt trigger circuit.

20. Time-base section.

21. To activate the gate section.

22. The gate section.

23. 473,020 ± 10 Hz is the frequency. Accuracy is $\frac{10}{4.73 \times 105} \times 100$ percent = 0.002 percent.

24. By taking readings for progressively longer time-gate intervals.

25. The accuracy decreases.

26. A VFO, a modulating circuit, and an output attenuator.

27. A klystron-type oscillator.

28. The using organization.

29. TO 33K–1–01, *Calibration Procedures and Responsibilities.* This TO lists all test equipment and tells who is responsible for its calibration.

CHAPTER 6

1. *a.* A definite 100-percent point is not known.
   b. High emission does not necessarily indicate a good tube.
   c. The tube is not tested during simulated operating conditions.

2. 70 percent.

3. (a) $\frac{I_p}{E_g}$.

   (b) It indicates the amplifying ability of a tube.

4. When an AC test signal is applied to the grid, the dynamic method of measuring transconductance is being used.

5. The short-circuit test. If the tube is shorted and other tests are made, the high current could damage the tube tester.

6. Noise.

7. Noise when the tube vibrates.

8. If the emission decreases more than 10 percent during the filament activity test, the tube is considered substandard.

9. The ratio of the reverse-to-forward resistance.

10. The reverse current-versus-voltage curve.

11. Breakdown or Zener.

12. By the symbol I_{co}.

13. H_{fb} and h_{fe}.

14. $h_{fe} = \frac{0.96}{1 - 0.96} = \frac{0.96}{0.04} = 24$.

15. $h_{fb} = \frac{50}{50 + 1} = 0.98$.

STOP— **1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.** **2. USE NUMBER 1 PENCIL.**

30455 01A 22

VOLUME REVIEW EXERCISE

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use only medium sharp #1 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than with a #1 black lead pencil.

NOTE: TEXT PAGE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE. In parenthesis after each item number on the VRE is the *Text Page Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Text Pages* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual VRE items you missed*. Go to the VRE booklet and locate the *Text Page Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

Multiple Choice

1. (001) As a supervisor, your primary objective is responsibility to

   a. your unit.
   b. the mission.
   c. your superiors.
   d. your subordinates.

2. (003) "Praise in public, criticize in private" is a part of what principle of supervision?

   a. Telling people in advance about changes that will affect them.
   b. Letting each worker know how he is getting along.
   c. Making the best use of each person's ability.
   d. Giving credit where credit is due.

3. (003) When you review a man's record in solving a personnel problem, you are

   a. weighing and deciding.
   b. checking results.
   c. getting the facts.
   d. taking action.

4. (004) Production controls include all of the following *except*

   a. time budgeting.
   b. scheduling of work.
   c. management analysis.
   d. mechanical standards.

5. (005) Course 3ABR30334 is

   a. an Air National Guard course.
   b. a basic technical course.
   c. a Reserve officer course.
   d. an instructor course.

6. (007) On-the-job training is conducted

   a. within the unit where the airman is assigned.
   b. at resident technical schools as graduate training.
   c. in special schools established by Hq USAF.
   d. solely through correspondence courses and group study classes.

7. (008) Which of the following is the source of authority establishing the content of technical training courses?

   a. Specialty Training Standard.
   b. *Airman Classification Manual.*
   c. Job Proficiency Guide.
   d. Unit Document Listing.

8. (011) Approximately what percent of all USAF ground accidents result from Government motor vehicle operations?

   a. 10 percent.
   b. 20 percent.
   c. 30 percent.
   d. 40 percent.

9. (012) Which of the following is *not* a type of fire?

a. Type A.
b. Type B.
c. Type C.
d. Type D.

10. (012) Soda-acid fire extinguishers have an effective range of

a. 40 to 50 feet.
b. 30 to 40 feet.
c. 15 to 30 feet.
d. 3 to 6 feet.

11. (013) If you work around radioactive material or materials, which of the following is *not* true?

a. Wear protective clothing.
b. Do not eat while in the area.
c. Good hygiene is unnecessary.
d. Wear a film badge.

12. (015) Which Air Force publication prescribes the forms to be used for accident reporting?

a. AFR 27-4.
b. AFR 100-27.
c. AFR 124-7.
d. AFR 127-4.

13. (016) A tourniquet, once applied, should be loosened only if

a. a doctor does it.
b. the blood has stopped gushing.
c. the wound is close to the foot.
d. the patient is turning blue in his face.

14. (017) Artificial respiration must be applied if the patient

a. is not breathing.
b. has been poisoned.
c. is weak from loss of blood.
d. is suffering from a back injury.

15. (018) Which method of artificial respiration is the most effective?

a. Chest-pressure-arm-lift.
b. Back-pressure-arm-lift.
c. Back-pressure-hip-lift.
d. Mouth-to-mouth.

16. (019) Concerning the mouth-to-mouth method of artificial respiration, you should force air into the victim's lungs approximately how many times per minute for an adult and for a child, respectively?

a. 8 and 12.
b. 16 and 12.
c. 12 and 20.
d. 20 and 16.

17. (020) An airman driving an Air Force vehicle is safer than when driving his personally owned automobile because

a. his Air Force job has built-in safety reminders.
b. Air Force vehicles are in perfect mechanical condition.
c. the Air Force has special punishments for careless drivers.
d. driving Air Force vehicles requires more skill than driving private ones.

18. (022) Which of the following is included in preventive maintenance?

a. Inspection and installation.
b. Inspecting, cleaning, and lubricating the equipment.
c. Bench check of equipment, siting, and lubrication.
d. Climatic deterioration prevention and periodic overhaul.

19. (023) Which of the following abrasives should you use to clean relay contacts?

a. Coarse sandpaper.
b. Emery cloth.
c. Crocus cloth.
d. Steel wool.

20. (024) Which of the following is *not* a true statement about fungi?

a. Fungus is a form of animal life that feeds on paper and cotton.
b. Fungi thrive in high humidity.
c. Fungus growth causes deterioration of insulation.
d. Fungi cause decay.

21. (025) Which of the following is a precaution to observe when using an ohmmeter?

a. Remove any transistors that may be damaged by the ohmmeter.
b. Apply low voltage only to the circuit.
c. Turn on the high voltage first.
d. Observe polarity across resistances.

22. (026) Which of the following is usually measured with a meter containing a bolometer?

a. DC power.
b. AC power in the audio range.
c. Percent of modulation.
d. UHF transmitter output power.

23. (031) Refer to figure 19 of the text. The primary of the output transformer of stage 2 is open. Which of the following statements is true?

a. There is no output with a signal injected at point A.
b. The output is weak with a signal injected at point D.
c. There is no output with a signal injected at point F.
d. The output is normal from all points of signal injection.

24. (032) What is the final step in corrective maintenance?

a. Giving the equipment a performance check.
b. Isolating the trouble to a subsystem.
c. Replacing the defective component.
d. Eliminating all properly functioning subsystems.

25. (033) What type of printed circuit is formed by indenting a metal foil into an insulating base and removing the unwanted raised portion?

a. Etched.
b. Embossed foil.
c. Chemically deposited.
d. Electrolytic indentation.

26. (033-034) What wattage rating soldering iron is most appropriate for work with printed circuits?

a. 5-watt.
b. 35-watt.
c. 100-watt.
d. 250-watt.

27. (034) An advantage of the complete component replacement method of replacing components on a printed-circuit board, as compared to the service terminal component replacement method, is that the former

a. can be easily done by squadron maintenance personnel.
b. does not require the use of a vise or heat sink.
c. requires standard size tools only.
d. is neater and more effective.

28. (036) You can consider repairing a crack in a printed-circuit board when

a. the crack runs under a conductor.
b. the crack is parallel to the mounting edge of the board.
c. the crack does not start at either of the mounting edges.
d. there are no more than three repairable cracks on the board.

29. (037) When replacing a transistor, what is the most important thing to remember?

a. Not to apply an excessive amount of heat.
b. Not to use any type of pliers to hold or shape the transistor leads.
c. To leave all excess solder remaining on the eyelet to solder the new component.
d. Always use a very hot soldering iron to prevent holding the iron in place for long intervals.

30. (038) When working with coaxial cables used in electronic equipment, you should check to be sure that

a. spot ties are always used.
b. they are loosely bent to prevent damage.
c. the clamps fit around the cable tightly.
d. they do not have a bend radius of more than six times the cable diameter.

31. (040) Which level of maintenance performs cleaning where such cleaning does not require disassembly of the equipment?

a. Depot.
b. Field.
c. Limited.
d. Organizational.

32. (041) Which of the following units collects, maintains, and analyzes data relating to the maintenance complex?

a. Programs analysis.
b. Control analysis.
c. Data control.
d. Data surveillance.

33. (042) Which element of maintenance control manages and controls those maintenance actions scheduled in the maintenance plan which change equipment or facility status?

a. Materiel control
b. Plans and scheduling.
c. Quality control.
d. Job control.

34. (042) All of the following are included in Quality Control *except*

a. Technical order library.
b. Deficiency analysis.
c. Deficiency control.
d. Standardization and evaluation.

35. (044) You have discovered that Airman Jones was loaned to another work center yesterday for 4 hours, but you thought at the time that he was at the orderly room and turned in an exception card to reflect this situation. To correct this erroneous entry that is charged to your work center, you should turn in only

a. a transferee card.
b. a correction card.
c. a correction card and a backdated card.
d. another exception card with the corrected information.

36. (045) Which of the following is *not* a responsibility of Maintenance Control?

a. Act as the critical item monitor for the maintenance complex.
b. Provide the maintenance input to the programming function.
c. Maintain liaison with the maintenance property custodians.
d. Identify and verify not-operationally-ready-supply (NORS) conditions.

37. (046) Equipment deficiencies of a routine nature are normally reported through the

a. maintenance data collection system.
b. USAF product improvement program.
c. maintainability program.
d. reliability program.

38. (046) What type of technical order will direct the corrective action when a condition exists that may cause the loss of an aircraft?

a. Urgent action.
b. Record action.
c. Routine action.
d. Immediate action.

39. (048) TO 0-1-01 is the index to

a. Air Force NI&RTs.
b. general aircraft TOs.
c. airborne electronics TOs.
d. ground electronics TOs.

40. (048) TO 0-2-1 provides

a. dates of all current TOs.
b. an alphabetical list of equipment TOs.
c. a list of technical orders in numerical order.
d. an alphabetical list of commercial publications.

41. (048-049) The procedures for distribution and storage of TOs is explained in

a. TO 00-5-1.
b. TO 00-5-2.
c. TO 0-1-01.
d. TO 0-4-1.

42. (049) Concerning a TO number composed of three parts separated by dashes, what is true of the part following the first dash?

a. It is the subgroup designator.
b. It is the major group designator.
c. It is the series number.
d. It is the base number.

43. (050) TO deficiencies are reported if

a. the information in the TO is incorrect, to whatever degree.
b. they adversely affect performance of the mission.
c. a drawing is affected.
d. a change is impending.

44. (053) Which statement describes electrostatic deflection in a CRT?

a. Instantaneous beam deflection toward the positive plate.
b. Instantaneous beam deflection toward the negative plate.
c. Circular sweep deflection caused by a rotating potential around the deflection coil.
d. Beam deflection proportional in length to the deflection voltage frequency.

45. (054) What is the vertical deflection sensitivity of an oscilloscope if a 150 VDC applied to its vertical deflection plates deflects the spot 3 centimeters?

a. 0.2-mm/volt.
b. 0.5-mm/volt.
c. 4.5-mm/volt.
d. 5-mm/volt.

46. (054) What is the amplitude of the voltage applied if the spot is deflected 2.5 inches on an oscilloscope that has a deflection factor of 50 VDC/inch?

a. 0.05 volt.
b. 12.5 volts.
c. 20 volts.
d. 125 volts.

47. (055) What is usually the output of the low-voltage power supply of an oscilloscope?

a. Over 1000 volts.
b. Between 500 volts and 750 volts.
c. Between 250 volts and 400 volts.
d. Less than 200 volts.

48. (055) To obtain full-scale deflection on a cathode-ray tube, how much internal voltage is applied by the vertical and horizontal amplifiers to the deflection plates?

a. Several millivolts.
b. Several volts.
c. Several hundred volts.
d. Several thousand volts.

49. (056-057) A portion of a test signal is applied to the grid of the thyratron within an oscilloscope to obtain

a. focus.
b. intensity control.
c. synchronization.
d. positioning.

50. (057) A thyratron sweep generator operates in what mode of operation?

a. One-shot.
b. Blocked.
c. Triggered.
d. Free-running.

51. (059) What is the distinguishing feature of a synchroscope?

a. Its triggered sweep.
b. Its voltage calibrator.
c. Its marker generator.
d. Its sweep calibrator.

52. (061) Which of the following are least affected by the retrace time of an oscilloscope?

a. Sine waves.
b. Square waves.
c. High-frequency waveforms.
d. Low-frequency waveforms.

53. (061) What is the purpose of the blanking pulse and to what CRT element is it applied?

a. It is applied to the cathode and drives it to cutoff during retrace time.
b. It is applied to the control grid and drives it to cutoff during retrace time.
c. It is applied to the cathode and holds it at cutoff during equipment warmup.
d. It is applied to the control grid and holds it at cutoff during equipment warmup..

54. (063) What two oscilloscope controls interact to the extent that an adjustment of one usually requires an adjustment of the other?

a. Focus and intensity.
b. Focus and positioning.
c. Gain and positioning.
d. Frequency and gain.

55. (064) The optimum height-to-width ratio for general-purpose waveform displays is approximately

a. 1:2 or 2:1.
b. 2:1 or 2:3.
c. 2:3 or 4:5.
d. 4:5 or 5:4.

56. (065) The controls that are used to shift the entire CRT display to any desired portion of the viewing area are the

a. centering controls.
b. deflection controls.
c. positioning controls.
d. displacement controls.

57. (066) What is the frequency of the time-base generator if five complete cycles of a 25-kHz test signal are displayed on the scope?

a. 2.5 kHz.
b. 5 kHz.
c. 30 kHz.
d. 125 kHz.

58. (067) The purpose of the synchronizing control is to

a. apply a portion of the vertical signal to the sweep circuit.
b. apply a portion of the horizontal signal to the sweep circuit.
c. adjust the amplitude of the sweep signal.
d. adjust the frequency of the sweep signal.

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59. (069) To produce markers by intensity modulation, the marker signal is fed to the

a. vertical input.
b. horizontal input.
c. sync input.
d. Z-axis input.

60. (069-070) A series of positive-going marker pulses applied to the cathode of a CRT will appear in the trace as

a. bright spots.
b. dark spots.
c. positive-going pulses.
d. negative-going pulses.

61. (071) Which of the following does not cause a "grass" display?

a. A bad input potentiometer.
b. Microphonic amplifier tubes.
c. Poor input connections.
d. A faulty intensity control.

62. (075) Which of the following best describes how the sweep generator of the 585A oscilloscope is triggered when operating in its internal triggering mode?

a. A sample of the vertical signal is fed to the sweep generator as a trigger signal.
b. A 6.3-volt filament signal is fed to a trigger generator circuit which, in turn, produces a sweep generator trigger.
c. A sample of the vertical signal is fed to the trigger generator which, in turn, develops a sweep generator trigger.
d. A 6.3-volt filament signal is used to trigger the sweep generator via a differentiating network.

63. (077) An important point to remember about the TIME PER CENTIMETER control of an oscilloscope is that it

a. varies the rate of charge of the sawtooth sweep generator, not the amplitude of the output voltage.
b. varies the amplitude of the sawtooth sweep generator output voltage, not the rate of charge.
c. causes the holdoff circuit to trigger a horizontal sweep voltage.
d. triggers the sweep multivibrator to the rest position after each horizontal sweep.

Special Situation. Questions 64 through 67. The controls on a Tektronix 585A (see figure 54 of the test) are set as follows:

"A" TRIGGERING SOURCE - INTERNAL
"A" TRIGGERING SLOPE - POSITIVE
"A" TRIGGERING LEVEL - 0
"A" TIME/CM - 50 μsec
HORIZONTAL DISPLAY - "A"
"A" STABILITY - clockwise until the sweep appears and then counterclockwise until it just disappears.

64. (075-077) The triggering source switch is switched to the EXTERNAL position and two related signals are applied--one to the VERTICAL INPUT jack and one to the TRIGGER INPUT jack. This results in

a. an unsynchronized display.
b. no display.
c. a sweep starting when the vertical input passes through 0 in the positive direction.
d. a sweep starting when the trigger input passes through 0 in the positive direction.

65. (078) When a signal is applied to the VERTICAL INPUT jack with "A" TRIGGERING SOURCE on INTERNAL, a display is obtained. Where does this display start?

a. At 0 and goes negative.
b. At 0 and goes positive.
c. At maximum positive and goes negative.
d. At maximum negative and goes positive.

66. (079) A signal of unknown frequency is applied and 2½ cycles are displayed. What is the signal frequency?

a. 5 kHz.
b. 10 kHz.
c. 50 kHz.
d. 100 kHz.

67. (079) A 40-kHz signal is applied as a vertical input. How many cycles are displayed?

a. ½.
b. 2.
c. 20.
d. 40.

Special Situation. Questions 68 through 71. The Tektronix 585A (refer to figure 54 of the text) is set up as follows:

HORIZONTAL DISPLAY switch - "B"
"B" TRIGGERING SOURCE - INTERNAL
"B" TRIGGERING SLOPE - (-) NEGATIVE
"B" TRIGGERING LEVEL - (0) ZERO
"B" STABILITY - set for triggered operation
"B" TIME/CM - 0.2 ms
"A" STABILITY - fully CW (free-running position)
"A" TIME/CM - 0.1 ms
A 5-kHz square wave is applied to the VERTICAL INPUT jack.
DELAY-TIME MULTIPLIER - 5.0

68. (078-080) With the stated conditions, which of the following best describes the display obtained?

a. A 10-cycle display of uniform intensity.
b. A 1-cycle display of uniform intensity.
c. A 10-cycle display with the last 5 cycles intensified.
d. A 1-cycle display with the positive alternation intensified.

69. (080-083) Which of the following best describes the display obtained when the HORIZONTAL DISPLAY switch is placed in the "B" INTENSIFIED BY "A" position?

a. A 5-cycle intensified trace.
b. A 5-cycle trace of normal intensity.
c. A 10-cycle trace of normal intensity.
d. A 10-cycle trace with the last 5 cycles intensified.

70. (080-083) How must the controls be set to present a 10-cycle display with the second cycle intensified?

a. HORIZONTAL DISPLAY to "B" INTENSIFIED BY "A," "B" TIME/CM to 0.5 millisecond, and DELAY-TIME MULTIPLIER to 1.0.
b. "B" TIME/CM to 0.5 ms, "A" TIME/CM to 20 μsec, and the DELAY-TIME MULTIPLIER to 1.0.
c. HORIZONTAL DISPLAY to "A" DELAYED BY "B," "A" TIME/CM to 20 μsec, and DELAY-TIME MULTIPLIER to 2.0.
d. HORIZONTAL DISPLAY to "B" INTENSIFIED BY "A," "A" TIME/CM to 20 μsec, and DELAY-TIME MULTIPLIER TO 1.0.

71. (084) Which of the following best describes the display obtained when the HORIZONTAL DISPLAY switch is placed in the "A" DELAYED BY "B" position?

a. A 10-cycle trace with the last 5 cycles intensified.
b. A 10-cycle normal intensity trace.
c. A 5-cycle normal intensity trace.
d. A 5-cycle intensified trace.

72. (081) When operating the Tektronix 585A in the "B" INTENSIFIED BY "A" sweep function, how is unblanking accomplished?

a. By the A sweep unblanking pulse only.
b. By the B sweep unblanking pulse only.
c. By both the A and B sweep unblanking pulses.
d. By the A sawtooth sweep voltage.

73. (083) When operating the 585A oscilloscope, how is the sweep trigger initiated when the HORIZONTAL DISPLAY SWITCH is in the "A" SINGLE SWEEP position?

a. The B sweep sawtooth is fed to a pickoff circuit which, in turn, develops an A sweep trigger.
b. An external trigger input is fed directly to the A sweep generator.
c. The sweep trigger is produced by depressing the RESET button.
d. The sweep trigger is produced by the A trigger generator.

74. (085-086) When checking the phase relationship of two signals by using Lissajous patterns, you should always

a. set the amplitude of both input signals so that each signal gives the same amount of vertical deflection.
b. set the vertical horizontal input attenuation for equal horizontal and vertical deflection.
c. use one signal to trigger the A sweep and the other signal to trigger the B sweep.
d. use an external trigger of known relationship to the signals under test.

75. (087) Refer to figure 54 of the text. Concerning the dual-trace plug-in unit, when the INPUT selector switch is in the AC position, which choice is correct?

a. The DC reference level of AC signals may be checked.
b. A capacitor is placed in series with the INPUT jack.
c. The input signal is amplified and fed to the horizontal plates.
d. The INPUT jack is connected to the primary of an isolating transformer.

76. (089-090) Two calibration checks frequently performed on an oscilloscope are

a. sweep amplitude and astigmatism.
b. vertical input and attenuator probe.
c. volts per centimeter and astigmatism.
d. volts per centimeter and attenuator probe.

77. (090) A 10:1 attenuator probe is connected between the CAL OUT jack and the "A" VERTICAL INPUT jack (refer to figure 65 of the text). The amplitude calibrator control is set to its 2-volt position and the "A" VOLTS/CM control is set to 0.5 volt. The "A" INPUT control is in the AC position and the MODE control is set to "A" only. How many centimeters should the signal occupy vertically?

a. 4.0.
b. 2.5.
c. 0.4.
d. 0.25.

78. (092) When using a high-voltage probe with a VOM,

a. a multiplier resistor is unnecessary.
b. the multiplier resistor is of low value.
c. the input resistance is constant.
d. the multiplying factor changes with the range used.

79. (093) What is the maximum voltage rating of most scope input terminals?

a. 400 volts.
b. 600 volts.
c. 800 volts.
d. 1000 volts.

80. (094-095) Refer to figure 77,B, of the text. A capacitive voltage divider consisting of a 240-$\mu\mu$f and a 60-$\mu\mu$f capacitor has 100 volts as its input. If the output is taken across the 240-$\mu\mu$f capacitor, what is the step-down ration of the voltage divider?

a. 5:1.
b. 5:2.
c. 4:1.
d. 3:1.

81. (095) In order that the high-voltage capacitance divider probe not load the circuit under test, the input of the probe must contain

a. an extremely high impedance.
b. a very large capacitance.
c. an extremely low impedance.
d. a high-resistance shunt.

82. (096) When using a scope to perform high-frequency circuitry tests, capacitive loading of the circuit under test is virtually eliminated by

a. elimination of cable shielding.
b. using a high-resistance isolation probe.
c. adding series inductance to cancel the capacitive reactance.
d. detuning the circuit under test until after the DC measurements have been made.

83. (098) To have sufficient deflection for a good display, a high-voltage probe should not reduce the test signal below approximately

a. 5 volts.
b. 1 volt.
c. 0.5 volts.
d. 0.1 volt.

84. (100) The accuracy of the electrodynamic wattmeter is seriously affected by current exceeding

a. 5 amperes.
b. 10 amperes.
c. 20 amperes.
d. 50 amperes.

85. (100) Above what frequency does the accuracy of an electrodynamic wattmeter decrease considerably?

a. 60 Hz.
b. 200 Hz.
c. 500 Hz.
d. 1000 Hz.

86. (101) In what type meters are thermistors commonly used for the measurement of low power at high frequencies?

a. Wattmeters.
b. Bolometers.
c. Calorimeters.
d. Wavemeters.

87 (103) The reaction wavemeter is preferred for measuring

a. frequencies at low-power levels.
b. frequencies at high-power levels.
c. power at high frequencies.
d. power at low frequencies.

88. (104-105) What instrument can be used to determine frequency of a tuned circuit before power is applied to the circuit?

a. Absorption wavemeter.
b. Reaction wavemeter.
c. Grid-dip meter.
d. Q-meter.

89. (105) Which of the following is a precision instrument which uses a calibrated variable-frequency oscillator?

a. Electronic voltmeter.
b. Heterodyne-frequency meter.
c. Absorption wavemeter.
d. Fluxmeter.

90. (106) What circuit is usually employed at the variable-frequency oscillator of a heterodyne-frequency meter?

a. Crystal oscillator.
b. Colpitts oscillator.
c. Hartley oscillator.
d. Electron-coupled oscillator.

91. (108) What is the function of a Schmitt trigger circuit in a frequency counter?

a. Divider.
b. Multiplier.
c. Reset.
d. Squarer.

92. (111) In which section of a frequency counter are you likely to find a thyratron tube?

a. Gate.
b. Reset.
c. Input.
d. Display.

93. (112) If the counting time of a frequency counter is 0.01 second and the five-digit readout is 05783, what is the frequency under test?

a. 57.83 Hz.
b. 578.3 Hz.
c. 57,830 Hz.
d. 578,300 Hz.

94. (112-113) How can the ratio of two frequencies be determined using a frequency counter?

a. Use the higher frequency as the gating signal and the lower frequency as the input signal.
b. Use the lower frequency as the gating signal and the higher frequency as the input signal.
c. Start the timing gate with the lower frequency signal and stop it with the higher frequency signal.
d. Take two readout readings and divide the higher by the lower.

95. (113) What type of AM is most often used with LC oscillators of signal generators?

a. Pulse.
b. Gated.
c. Sinusoidal.
d. Square wave.

96. (114) What technical order lists all test equipment in the Air Force inventory and tells who is responsible for its calibration?

a. TO 0-1-33.
b. TO 33-1-14.
c. TO 31-1-141.
d. TO 33K-1-100.

97. (116) Which choice is correct concerning the emission-type tube tester?

a. It checks only the plate current developed.
b. It test the 100-percent emission point.
c. It shows the ability of the grid to control current.
d. It indicates conclusively the condition of a tube.

98. (117) A voltage or power-amplifier tube is considered defective when its transconductance decreases to what percent of specified value?

a. 50 percent.
b. 60 percent.
c. 70 percent.
d. 80 percent.

99. (118-119) By increasing the sensitivity of the indicating device, a tube tester designed to test for short circuits may be used to test for

a. transconductance.
b. low emission.
c. gassy conditions.
d. microphonics.

100. (119) Cathode leakage caused by particle breakage will

a. not materially affect the tube's operation.
b. cause microphonic noise
c. completely short the cathode.
d. burn out the filament.

101. (120) The filament activity test is based on the principle that no appreciable decrease in emission of an electron tube will be caused by decreasing its rated heater voltage by what percent?

a. 5.
b. 10.
c. 15.
d. 20.

102. (121) Refer to figures 113 and 114 of the text. The action of which listed component shown in figure 113 is primarily responsible for the combination of the individual traces shown in figure 114 into the seemingly composite trace shown in figure 114.C?

a. S1.
b. S2.
c. S3.
d. K1.

103. (123) What is the leakage current flow between collector and base sometimes referred to as?

a. Collector cutoff current.
b. Punch-through current.
c. Zener current.
d. Input base current.

104. (124) How many hybrid parameters are there for a transistor in any one configuration?

a. 3.
b. 4.
c. 12.
d. 15.

105. (124) If a transistor has its $h_{fe} = 49$, what is its common base forward current gain?

a. 50.
b. 49.
c. 1.02.
d. 0.98.

106. (125) Refer to figure 124 of the text. Which choice is correct concerning meter M when the selector is in position 2?

a. Reads the current through R1.
b. Reads the voltage supplied by G2.
c. Reads the voltage drop across R1.
d. Connected between the emitter and ground.

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CDC 30455

TELEVISION EQUIPMENT REPAIRMAN

(AFSC 30455)

Volume 1

Equipment Maintenance

Extension Course Institute

Air University

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Preface

THIS COURSE consists of three volumes. It is designed to further your training toward the achievement of 5- and 7-level proficiency. If you are training to attain a 5 skill level, ycu should complete CDC 30000 in addition to this course. If you are training to attain a 7 skill level, you should complete CDC 30001 in addition to this course. We bring this to your attention because CDC 30455 is a TV specialty course. It does not cover JTS items that are common to other 30 career field specialties. Such items are contained in CDC 30000 and CDC 30001 for 5- and 7-skill-level training, respectively. Although all the other JTS items are covered in this course, you must realize that some JTS knowledge requirements will be met fully when you have acquired the related proficiency on specific equipments. Our treatment endeavors to give you knowledge so that you can more readily understand the principles that underlie the operation of TV equipments. This knowledge will facilitate further training on TV equipments and better enable you to cope with TV maintenance problems.

Chapter 1 deals principally with the prime equipments that make up a TV system. However, we discuss first your specialty in a general manner by identifying 5- and 7-skill-level responsibilities, classifying systems, and describing Air Force applications of television. Chapter 2 covers all types of TV power supplies to preclude unnecessary repetition in the chapters that follow. In chapter 3 we progress from the simple noninterlace sync generator to the more complex interlace types. The units of a camera chain are functionally analyzed in chapter 4. Chapter 5 covers the various types of monitors employed in a TV system. Microphones, audio amplifiers, and audio consoles are discussed in chapter 6. Our final chapter is devoted to color TV. We point out the special requirements of the standard color TV system and describe the equipments peculiar to this system.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to Tech Tng Cen (TSOC), Keesler AFB, MS 39534.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development, Study Reference Guides, Chapter Review Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If he can't answer your questions, send them to ECI, Gunter AFB, Alabama 36114, preferably on ECI Form 17, Student Request for Assistance.

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Changes

Page iii. par. 2. line 3. Delete "classifying systems."

Page iii. par. 3. Delete and replace with the following two paragraphs

"If you have questions on the accuracy or currency of the subject matter of this text. or recommendations for its improvement. send them to Tech Tng Cen (TSOC). Keesler AFB. MS 39534.

"If you have questions on course enrollment or administration. or on any of ECI's instructional aids (Your Key to Career Development. Study Reference Guides. Chapter Review Exercises. Volume Review Exercise. and Course Examination). consult your education officer. training officer. or NCO. as appropriate. If he can't answer your questions. send them to ECI. Gunter AFB. AL 36114. preferably on ECI Form 17. Student Request for Assistance."

Page 1. intro.. line 11. Change "educaion" to "education."

Page 1. par. 1-3. lines 5 and 6. Change "produring" to "producing."

Page 2. par. 1-7. line 1. Change "Job Training Standard (JTS)" to "Specialty Training Standard (STS)."

Page 3. par. 1-7. line 4. Change "JTS" to "STS." Line 11. Change "JTS" to "STS." Par. 1-9. line 2. Change "JTS" to "STS." Line 4. Change "JTS" to "STS." Lines 5 through 9. Delete sentence beginning: "Also note that . . . ."

Page 4. Delete figure 2.

Pages 4 and 5. Delete paragraphs 1-16 through 1-20.

Page 5. 2-1. Delete the second sentence.

Pages 5 and 6. Delete paragraphs 2-2 through 2-6.

Page 6. par. 2-7. line 5. Insert "Department of Defense" before "DOD" and enclose DOD in parentheses.

Page 7. Delete paragraph 2-10.

Page 7. Delete figure 5.

Page 11. col. 1. line 11. Change "planned" to "panned."

In Section 2. renumber paragraphs.

Page 18. 5-2. line 7. Change "frequence" to "frequency."

Page 21. par. 5-14. line 7. Insert "regulated" between "the" and "voltage."

Par. 5-15. line 9. After "accordingly." insert "the change in base current."

Page 22. par. 5-16. line 1. Insert "unregulated voltage" between "if" and "Vu."

Page 24. par. 5-30. Delete "The" on line 14 and delete lines 15 through 31. Replace with the following: "Transistor Q3 and the base circuit of Q4 are the collector load of Q2. Q3 is a high impedance to a-c. but a low impedance to d-c. thus allowing the desired d-c current through Q2. The capacitor prevents spurious high-frequency oscillations. Zener Z2 establishes the reference for Q3. and amplifier operation is adjusted to the optimum condition with the variable emitter resistor. Any change in Q2 collector current will be felt on the base of Q4."

Page 25. par. 5-33. line 7. Delete the sentence beginning: "The circuit containing Q3 . . . ."

Page 25. par. 5-33. lines 11 and 12. Insert "emitter follower" between "of" and "Q4."

Page 28. Paragraph now numbered "5-41" should be "5-44." Change the first sentence to read: "The symptoms just mentioned for the open-circuited rectifier are the same for a short-circuited rectifier."

Page 29. par. 6-8. last line. Change "and" to "to."

Page 33. par. 6-30. Delete last sentence and replace with: "However. HV rectifier filaments will not normally be visible."

Page 70. par. 12-14. Change this paragraph to read:

12-14. *Sync section.* The signal at TP3 should have the same waveform as shown at TP1. This signal is capacitively coupled into the sync separator stage Q3. Q3 has no fixed forward bias and is cutoff. Only the most negative or sync portion of the input composite signal provides forward bias and drives Q3 into conduction. Thus. only the snyc signals are amplified and appear as positive pulses at TP4.

Page 82. par. 14-18. line 9. Change "velocity" to "dynamic."

Page 93. par. 16-6. line 3. Delete the sentence beginning "In the amplifier circuits. . . ."

Page 95. par. 16-19. line 4. After "attenuator." delete "is. as you already know. nothing more than a gain control; therefore, it."

Page 105. par. 18-26. last sentence. Delete "TO 31S4-1-1A and."

Page 115. col. 1. line 1. Add "hundred" between "several" and "thousand."

Workbook

Chapter Review Exercises

Page 2. item 2. Change "JTS" to "STS."

Page 2. Delete items 7. 8. 9. and 10.

Page 3. Delete items 11. 12. 13. 14 and 19.

Page 3. Delete item 16. Change "CDA" to "DCA."

MODIFICATIONS

Chapter 1 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

CHAPTER 2

Power Supplies

SUPPLYING THE proper amount and kind of power to electronic equipment is of the utmost importance. A faulty power supply will cause malfunctions that may seriously impair the performance of a TV system. It is therefore imperative for you to thoroughly understand the principles that underlie the operation of power supplies used for TV. In this chapter we will discuss various types of low-voltage and high-voltage power supplies found in both transmitting and receiving equipments. Significant differences in rectifier outputs will be brought to your attention. Regulator circuits incorporating solid-state devices will be analyzed to further your understanding of these devices and also to review principles applicable to electron tube regulators. For practice in diagnosing troubles, we will present symptoms and then proceed to determine the probable trouble.

4. Power Requirements

4-1. Most television equipments you will encounter are designed to operate on 115-volt and 60-cycle power. Line voltage variations of ±10 percent are generally tolerable. Such power is available from local electric companies. In localities where only higher voltages are provided, stepdown transformers can be installed. Where no commercial source of primary power can be had, it is necessary to resort to an engine-driven generator. Generator units ranging from 3 to 15 kw are employed for television service. Since these units do not accurately maintain 60 cps, you need bear in mind that synchronization problems may occur unless the sync generator is crystal controlled. Crystal control is also needed if the power is 50 cps instead of 60 cps. This will be discussed further in later chapters.

4-2. These and other sources of primary power (such as atomic-driven generators) are a-c, but we know that the bulk of the power required is d-c. Although d-c can be generated directly in many ways, rectification of a-c is the most practical means of obtaining the amounts needed to operate TV equipments. A-c to d-c power supplies also filter and regulate (if required) to provide the various d-c voltages and currents needed. From here on when we speak of a power supply, we will mean a unit that converts a-c to d-c power. It may or may not have a transformer input designed for a single-phase or polyphase line. It must have rectifiers and components for filtering the ripple to an acceptable level. In addition, for highly stable outputs, it will have a regulator. By presenting the various types of power supplies used in TV equipments at the outset of this course, we will avoid unnecessary repetition in later chapters.

4-3. From your experience and training you are aware that power supplies differ considerably in design and capacity. The power supplies needed in a TV system depend upon the types of equipment (camera, sync generator, monitor, etc.), the complexity of the equipment, and the components contained within a particular equipment. There are noteworthy differences due to the requirements peculiar to tubes, transistors, or other active components.

4-4. Tubes and transistors are used extensively in the many types of equipments that you will maintain. Generally speaking, tubes and transistors must be supplied well-regulated d-c voltages. As you know, receiver-type electron tubes commonly operate with voltages from about 100 to 300 volts, and transmitting types may be designed for plate voltages of 1,000 volts or more. By contrast, transistors ordinarily require only 5 to 20 volts; in fact, some operate at a fraction of a volt. Although transistors often draw as much current as electron tubes, they require far less power because of their low operating voltage. Furthermore, transistors and other solid-state devices do not consume power for emission as do thermionic tubes. You would therefore expect to find marked differences between d-c power supplies designed for tubes and

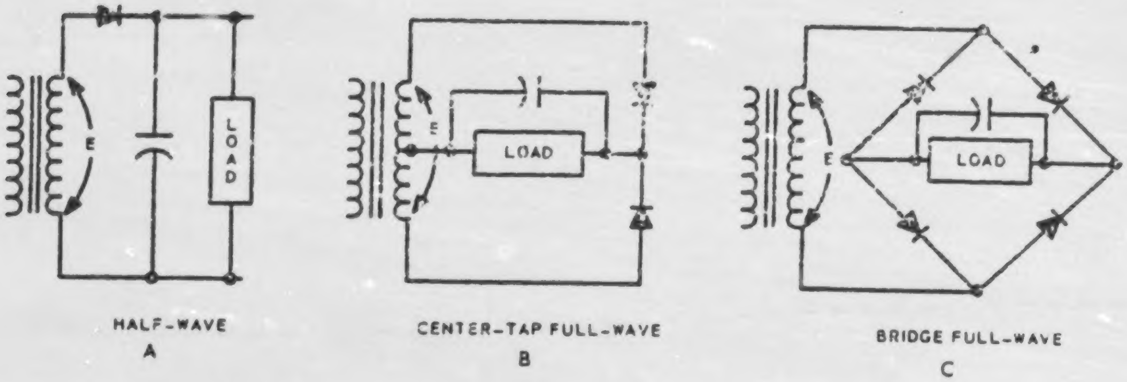


Figure 9. Basic rectifier circuits.

those designed for solid-state devices. These differences, however, are principally those of power and voltages rather than circuit configuration. Excepting the filament circuit for tubes, the same basic half-wave and full-wave rectifier arrangements are used to convert a-c to d-c power. Moreover, associated regulator circuits are essentially alike.

4-5. Camera tubes have special d-c requirements for highly stable voltages and currents. Several hundred volts for positive and negative potentials are needed. A typical power supply for an image orthicon must provide an adjustable current-regulated output of hundreds of milliamperes in addition to voltage-regulated outputs. We will study a transistorized version of such a supply shortly.

4-6. Picture tubes, particularly large ones, call for d-c voltages as high as 20,000 volts or more. High-voltage power supplies for picture tubes are ordinarily unregulated. This is because there is very little current drain and the load is virtually constant. The circuits to be analyzed in the final section of this chapter will point up the important features of high-voltage power supplies commonly used for these tubes.

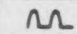
4-7. Besides tubes and solid-state devices, TV equipments contain control mechanisms, relays, and instruments that require d-c power. Consequently, provision must be made to supply these components, thus contributing to the differences you will find between power supplies.

5. Low-Voltage Power Supplies

5-1. You have previously studied basic rectifier circuits, filters, and regulators; therefore, it should suffice to briefly review the important information. Instead of reviewing electron-tube circuits, however, solid-state versions of familiar configurations are shown and discussed. Our analysis of selected regulator circuits is intended to further your understanding, which will enable you to troubleshoot more effectively and maintain low-voltage power supplies. The increasing use of solid-state devices for rectification and regulation justifies the attention given to them at this level of your training.

5-2. **Rectifier Arrangements and Characteristics.** The three basic rectifier configurations are illustrated in figure 9. These single-phase rectifier circuits have characteristics which are worth keeping in mind. As a maintenance man, you should know what to expect by way of d-c output, ripple frequence, and peak-inverse voltage (PIV) for a given a-c input. Figure 10 shows the approximate normal values for each arrangement. Compare the values and note the differences. The half-wave circuit is the simplest, but note its low ripple frequency. This, of course, means better filtering circuitry is required to obtain a satisfactory output. Also, the peak-inverse voltage across the diode (tube or solid-state rectifier) is about twice the applied a-c peak voltage (secondary for transformer input). Both full-wave types have the advantages of lower percent ripple, higher ripple frequency, and lower peak-inverse voltage.

5-3. To be sure you understand the meaning of the values given in figure 10, let us cite a

TYPE RECTIFIER	MAXIMUM D-C VOLTS	CAPACITOR INPUT FILTER PIV	RIPPLE FREQUENCY CPS	UNFILTER WAVEFORM
HALF-WAVE	1.4 E	2.8 E	f	
CENTER-TAP	0.7 E	1.4 E	2f	
BRIDGE	1.4 E	1.4 E	2f	

*NOTE E = AC APPLIED EFFECTIVE VOLTS (RMS)
f = FREQUENCY OF AC APPLIED

Figure 10. Table of values for basic rectifier circuits.

Page 18. After paragraph 4-7, add new paragraphs 4-8 through 4-24, including new chapter review exercises and answers.

4-8. To refresh your memory, the principles of solid state devices will be reviewed. Rather than attempt to present the physics involved in solid state theory, we will consider their effect on electron current flow in the external circuit.

4-9. The direction of current flow has confused many students. One theory has current flowing from positive to negative. This is called conventional current flow. Transistors increase the confusion by adding hole movement from positive to negative. The theory we will adopt is that of electron current flow. This is in the direction of electron drift, or from negative to positive. Refer to foldout 1, figure A (at the back of this supplement). In these solid state symbols, the arrowheads indicate the direction of conventional current flow. Because electron current flow is always toward the most positive potential, it will always be against the arrowhead.

4-10. **Semiconductor Material.** The ability of a material to conduct an electric current is directly proportional to the number of free electrons available in the material. Good conductors have many free electrons, whereas insulators have very few. Semiconductors fall between the two. A microscopic study reveals that most solids have a crystal structure. The atoms of crystals are arranged in a specific pattern or lattice. When an impurity is added to the semiconductor material, its atoms join the crystal structure pattern. Examples are shown in foldout 1, figure B. If the impurity atoms have more electrons than the semiconductor atoms, the lattice has extra or free electrons. This is called n-type material. If the impurity atoms added have less free electrons than the semiconductor atoms, the resulting crystal structure will have vacancies or holes due to this lack of free electrons. This is called p-type material. The n- and p-type impurities appreciably alter the conductivity of the semiconductor. They are diffused into the material to obtain a wanted value of conductance. The semiconductor is then said to be doped.

4-11. **Diodes.** A diode consists of a p-type and an n-type material joined in the manufacturing process. At this junction, a depletion region or space charge region is formed. This region, called a barrier potential, is an electric field or difference of potential caused by recombination. While it is not directly measurable, it is represented in foldout 1, figure C, as an imaginary battery. Note the polarity in relation to the n and p material.

4-12. *Bias.* An external battery connected across the diode, as shown on the left of figure D of foldout 1, is said to forward-bias the diode. The external and imaginary batteries are in series and aiding. Electron current will flow in the circuit from negative to positive. Increasing the external potential will increase the current. Unless current flow is limited by external circuitry, excessive forward bias will result in excessive heat and crystal structure breakdown. In a semiconductor, this heat causes a decrease in resistance and a further increase in current. This is thermal runaway and destroys the device.

4-13. Connecting the battery across the diode, as shown on the right of figure D of foldout 1, will reverse bias it. Because the external battery and the imaginary battery oppose each other, little or no current will flow. The imaginary battery or barrier potential will always equal the external voltage applied unless the material's limit is exceeded. Thus, if an external voltage larger than the maximum possible barrier potential is applied, the crystal structure will also break down and be destroyed.

4-14. *Rectification.* If we understand what happens when voltage is applied in either polarity, it is easy to see how the diode rectifies when forward-bias current flow is high. Reverse bias results in almost zero current flow. If an a-c signal is applied, electron current flows freely during one half cycle and little or no current flows in the other half cycle. Figure E of foldout 1 is the voltage-current characteristic curve for both bias conditions.

4-15. *Zener diodes.* Zener diodes are p-n junctions that change resistance greatly with a small change in applied voltage. They differ from normal p-n junctions in that a reverse bias of sufficient potential causes crystal breakdown and a charge emission but does not destroy the diode. Therefore, when a proper load resistor is placed in series with a Zener diode, large changes in applied voltage may occur without causing a change in voltage across the Zener diode. It can be seen that it has similar characteristics to the conventional gas-filled voltage regulator tube (VR). Like the VR tube, it also starts conducting at a particular voltage and continues to conduct varying amounts of current at a fixed voltage drop across the device. Because the Zener diode operates with reverse bias, it will be inserted in a circuit the opposite of a normal diode. In other words, in a circuit the arrowhead will point in the direction of electron current flow.

4-16. **Transistors.** In figure F of foldout 1, we have two p-n junctions in one crystal. The batteries have biased one junction in the forward direction and the other in reverse. Figure E of the foldout shows that for the same amplitude of applied voltage, the current for the forward bias is much greater than for the reverse bias. Therefore, a p-n junction biased in the forward direction is the equivalent of a low resistance and the p-n junction biased in the reverse direction is the equivalent of a high resistance. From the power formula ($P = I^2R$), you can see that for a given current the power developed in a high-resistance element is greater than that developed in a low-resistance element. Applying a signal to the low-resistance section (forward is increased, gate current increases. This gate current increase lowers the value of anode voltage necessary for breakover (forward breakover voltage). Normally, the SCR is operated well below forward breakover voltage and the gate signal is large enough to trigger or turn the device on.

4-24. When the device is triggered, it is independent of gate control. It remains in the high-conduction state until the holding current point is reached. Quick turnoff can be achieved by applying a reverse bias.

biased p-n junction) and taking it from the high-resistance element (reverse biased p-n junction) produces a power gain. This combination of p-n junctions has transferred the signal from a low-resistance circuit to a high-resistance circuit. The word "transistor" is a contraction of the terms "*trans*fer" and "re*sistor*."

4-17. The two junctions in figure F of the foldout are formed with two n-type materials and one p-type. This is called an n-p-n transistor. The junctions may also be formed with two p-type materials and one n-type. This is a p-n-p transistor. The three regions or sections are called the emitter, base, and collector. Normal operation has the emitter-to-base junction forward biased and collector-to-base junction reverse biased. Referring to figure A, foldout 1, the two types of transistors are shown. The arrowhead is on the emitter lead and indicates the direction opposite that of d-c electron current flow. The first letter of the transistor type indicates the polarity of the emitter with respect to the base. Therefore, the p-n-p type has the emitter positive with respect to the base. The n-p-n types have the emitter negative with respect to the base. Figure G of foldout 1 is an example of forward bias current flow in an n-p-n transistor. A p-n-p will have opposite polarities and direction of current flow. Consider the transistor in a circuit as a variable resistor in a voltage divider network. With no forward bias, the transistor is a very high resistance. As forward bias is applied, its resistance decreases and current increases. This will assist you in understanding the circuits described in this chapter.

4-18. Unlike the electron tube, the transistor is classified by circuit connections or configurations. Compare the transistor configurations and the well-known electron tube connections shown in figure H of the foldout. The common emitter configuration designated by CE corresponds to the conventional grounded cathode connection for the triode tube (figure H1 of the foldout). The common base, CB, and common collector, CC, configurations correspond to the grounded grid and cathode follower tube connections, respectively (see figures H2 and H3 of the foldout). We will use the letter designations CE, CB, and CC as indicated; the first C stands for common and the second capital letter identifies the electrode.

4-19. The predominant circuit configuration used with junction transistors is the common emitter. The CE current amplification factor is called the forward current transfer ratio; it is represented by beta, β, or h_{fe}. It reflects the effect that a change in base current, I_B, has upon collector current, I_C, with a constant collector-emitter voltage, V_{CE}. The value of β for a particular transistor can be found in a transistor manual.

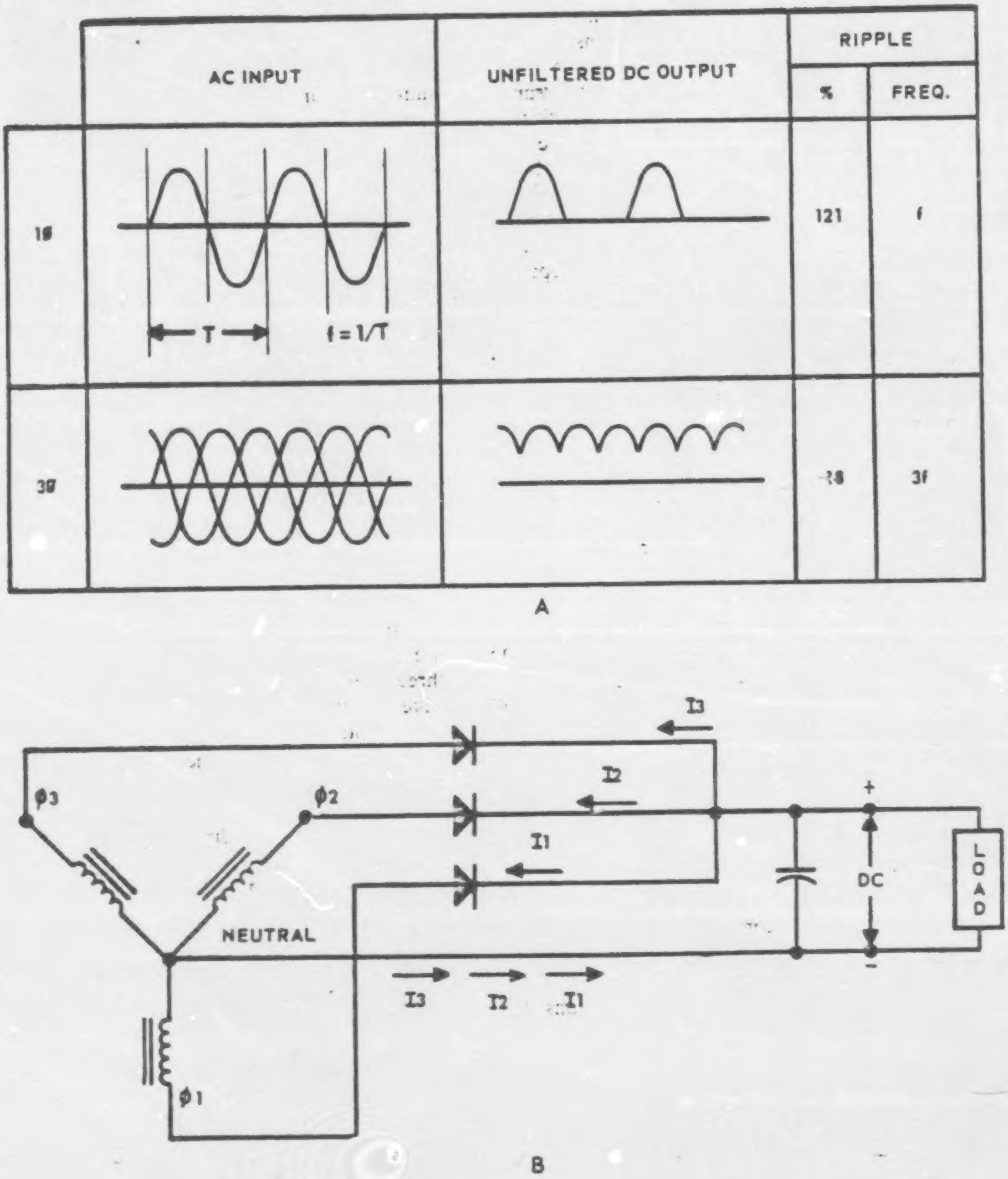
4-20. Two special-purpose devices are the unijunction transistor and the silicon controlled rectifier (SCR). These devices are designed for rapid switching purposes. Because they have two stable states, they are said to be bistable. Let's see how they operate.

4-21. **Unijunction Transistor.** Like a diode, the unijunction has a single p-n junction. However, it has two leads connected to the n region. Assuming the initial state to be that shown on the left of figure I of the foldout, the p-n junction is reverse biased. Consider the n region as a voltage divider (normally, about 5 K to 10 K ohms). If the total voltage from base 1 to base 2 is +10 volts, the voltage halfway between base 1 and base 2 is +5 volts. Since the p region is at 0 volts, the junction is reverse biased. Only a minute amount of emitter current can flow and conduction is at a low level. This state is maintained until the voltage on the emitter is increased to about +5 volts. Once the p-n junction becomes forward biased, current rapidly rises to a high-level state (right portion of figure I of foldout 1). Thus, whether the unijunction is in the high-level state or low-level state depends on the bias conditions. These devices can be designed to conduct heavily at any desired fraction of the applied base 2 voltage.

4-22. **Silicon Controlled Rectifier (SCR).** The SCR is basically a four-layer n-p-n-p semiconductor device. In the left-hand portion of figure J of the foldout, we see that the device has three contacts—a cathode, anode, and gate. Like a rectifier, it conducts mainly in one direction. Under reverse bias conditions, the device operates in a manner similar to a conventional rectifier as it has a slight reverse leakage current. However, it does not conduct immediately in the forward direction. As the voltage is increased at the anode, a value is reached at which the current increases rapidly. This is called the forward breakover voltage. At this point, the high internal resistance of the device changes to a low value and current increases rapidly. Now the device is considered "on" or triggered. It will remain in this high conduction state until the anode voltage drops to a value which cannot maintain the breakover current. This current is called holding current. Below this value of forward current, the SCR returns to its high-resistance state and current ceases to flow. Now the switch is "off." Follow the gate current curve in the right-hand portion of figure J of foldout 1.

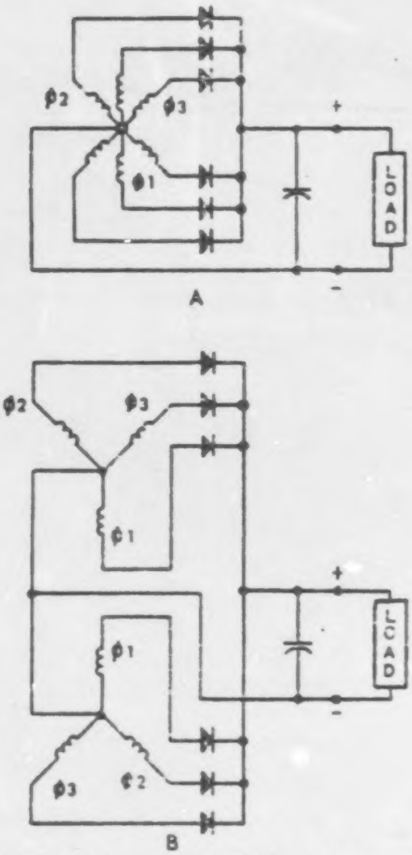
4-23. The breakover point of an SCR can be controlled by injecting a signal at the gate. Thus, it can be turned on and off at will. With no signal applied, gate current is zero. As the signal particular example. Assuming a 60-cps effective a-c input (E) of 300 volts, figure 10 tells us that the maximum d-c output for a center-tap full-wave rectifier is about 0.7E = 0.7 × 300v = 210v with a ripple frequency of 2f = 2 × 60 cps = 120 cps. The diodes must withstand a peak-inverse voltage of 1.4E = 1.4 × 300v = 420v. As you see, these values can be quickly and readily determined if you know the information contained in figure 10.

5-4. Having reviewed the basic single-phase rectifier circuits, let us now consider some three-phase circuits. Using a three-phase input greatly increases the quality of the output. You can see the reason for this in figure 11,A. The unfiltered output waveform clearly shows why the ampli-


AC INPUT
UNFILTERED DC OUTPUT
RIPPLE
%
FREQ.
1φ
T
f = 1/T
121
f
3φ
18
3f
A
φ3
φ2
φ1
NEUTRAL
I3
I2
I1
I3
I2
I1
+
DC
−
LOAD
B

A. COMPARISON OF SINGLE-PHASE AND THREE-PHASE HALF-WAVE RECTIFICATION B. THREE-PHASE HALF-WAVE RECTIFIER CIRCUIT

Figure 11. Half-wave Rectification.



A. CENTER-TAPPED Y SECONDARIES
B. SEPARATE Y SECONDARIES (PHASES ARE IN EFFECT CENTER-TAPPED)

Figure 12. Three-phase center-tap rectifier circuit.

tude of the ripple is greatly reduced when a three-phase unit is employed. Note the marked decrease in the percent of ripple. Observe also that the ripple frequency is tripled, which facilitates filtering and improves regulation.

5-5. Figure 11,B, shows a simple three-phase half-wave rectifier circuit. Trace out any one phase and it becomes apparent that the circuit is that of a single-phase half-wave rectifier. Thus, a three-phase unit is no more than a combination of three single-phase units. Since each phase is displaced by 120°, the filter is charged three times rather than once per cycle and the resultant output is the composite of the output of each phase.

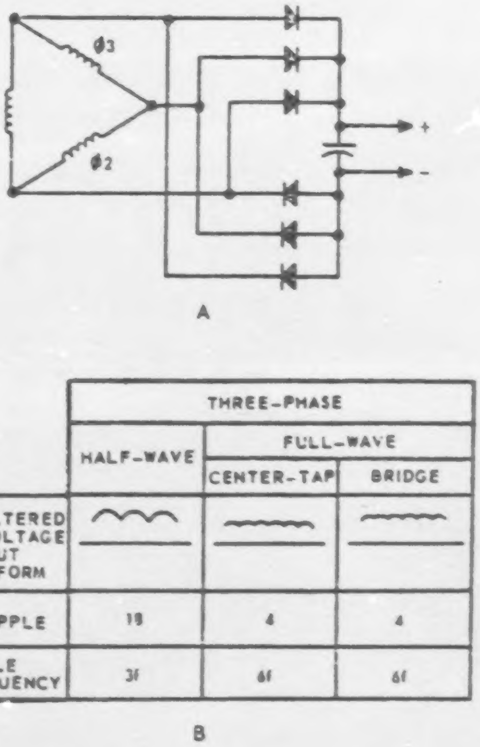
5-6. Because this rectifier unit requires more rectifiers and a three-phase source, it is larger and more costly than a single-phase unit. Like the single-phase unit, a three-phase unit can be transformerless. When transformers are used, the primary windings may be connected either delta (Δ) or wye (Y).

5-7. We have spoken only of a three-phase unit, but a polyphase half-wave rectifier may consist of any number of phases. It stands to reason that the greater the number of phases, the lesser the percent ripple and the better the output. Regardless of the number of phases, the operation of a polyphase unit is fundamentally that of single-phase units feeding a common load in time sequence.

5-8. Although polyphase units overcome the disadvantages of low-frequency ripple, a capacitor-input filter still develops a high PIV. Each rectifying diode must withstand approximately twice the peak secondary phase voltage (line-to-neutral voltage).

5-9. As with half-wave rectifiers, the d-c output of center-tap rectifiers can be improved by using a polyphase network. Two 3-phase networks are shown in figure 12. Notice that any one phase is identical to the single-phase center-tap rectifier circuit in figure 9,B. So again a polyphase rectifier can be regarded as a combination of single-phase rectifiers operating in time sequence to supply a common load.

5-10. A basic three-phase bridge rectifier working from a Δ secondary is shown in figure 13,A. Trace out a single phase and prove to



	THREE-PHASE		
	HALF-WAVE	FULL-WAVE	
		CENTER-TAP	BRIDGE
UNFILTERED DC VOLTAGE OUTPUT WAVEFORM			
% RIPPLE	18	4	4
RIPPLE FREQUENCY	3f	6f	6f

Figure 13. Three-phase bridge rectifier circuit.

yourself that the circuit is identical to the one shown in figure 9,C. The combined output of the three phases which are operating 120° apart produces a waveform that has a low-percent ripple (4 percent) and a high ripple frequency (six times the input frequency *f*). When we compare the output of the bridge rectifier with the other types in figure 13,B, we see that the bridge rectifier affords the advantages of full-wave rectification at a high d-c output voltage.

5-11. **Voltage Regulators.** Keeping the output of a d-c power supply constant is of critical importance in many TV applications. It may be absolutely necessary to use voltage regulators or current regulators in conjunction with the rectifier unit. Some power supplies will have both voltage and current regulation.

5-12. Regulator units may be quite simple, using a single thermistor VR tube or Zener diode. On the other hand, complicated units will use an array of tubes or solid-state devices. Although solid-state regulators are similar to electron-tube regulators, they can be fashioned in many different ways. The fact that either n-p-n or p-n-p transistors can be used permits considerable diversity in design. We will progress from the simple to the more involved circuits by explaining the operation of representative shunt and series type regulators.

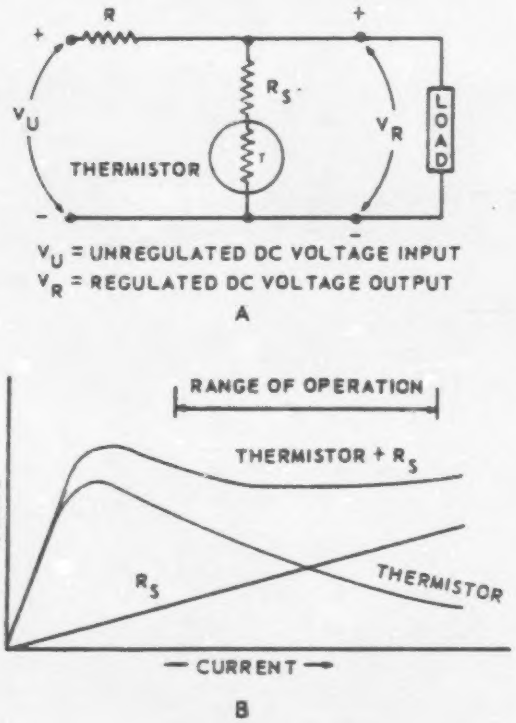


Figure 14. Thermister shunt regulator.

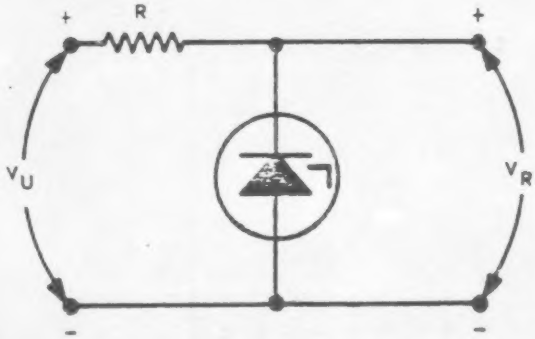


Figure 15. Zener diode regulator.

5-13. *Shunt types.* Two reasons for the use of shunt voltage regulators are: (1) their low cost in the simplest form and (2) their inherent overload and short-circuit protection. Essentially, a shunt voltage regulator consists of a limiting resistor in series with the load and a variable resistance component in parallel (shunt) with the load. The circuit shown in figure 14,A, is a simple shunt regulator unit. R is the series limiting resistor. The combination of R_s and the thermistor is the variable resistance that parallels the load. This circuit is capable of stabilizing the d-c output voltage against variations of input voltage and load (current drain) over comparatively wide ranges (see fig. 14,B). Although simple, it is very inefficient because of the power consumed in the regulator unit itself.

5-14. The Zener diode regulator circuit (see fig. 15) is comparable to the VR (voltage regulator) tube circuit. The voltage across the Zener diode is virtually constant and independent of current. Diode current must be limited by a series limiting resistor R of *proper* size. The operation of the circuit is very simple, since the voltage V_R, remains practically constant so long as the input and load variations stay within the specified limits of the Zener diode. Like VR tubes, Zener diodes can be connected in series to provide different regulated voltage values. They have numerous voltage and power ratings, with 5-percent, 10-percent, or 20-percent tolerances.

5-15. If the Zener diode regulator is not satisfactory, an arrangement like that shown in figure 16,A, may be used. Here we see a p-n-p transistor connected across the output to regulate the voltage. Note that the collector-to-base difference in potential is held constant by a Zener diode. Therefore, any change in voltage caused by either the input or load affects the base-to-emitter current I_B. Accordingly, ΔI_B is amplified by approximately the β factor, h_{FE}. The current change ΔI_C through the transistor

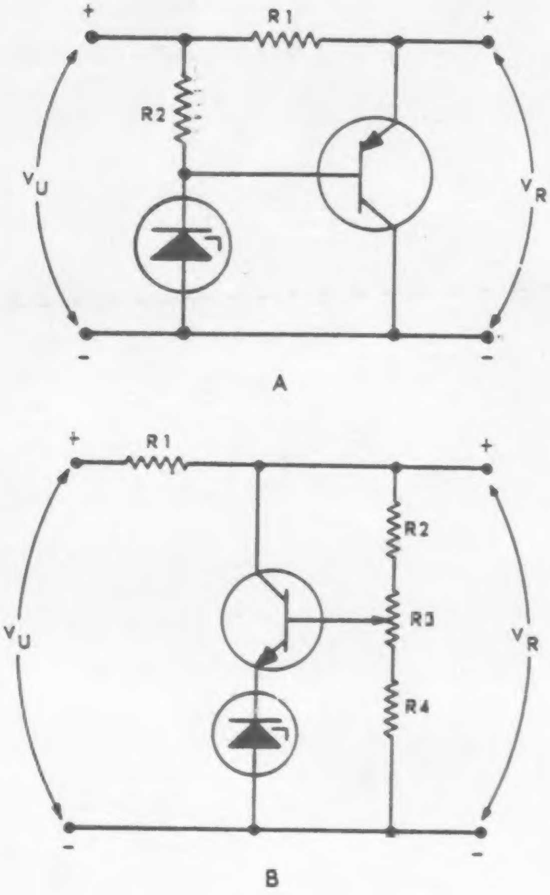


Figure 16. Transistor shunt regulator.

counteracts any voltage change. For example, suppose the load draws more current; the voltage on the load side would tend to decrease. Base current I_B will decrease and cause an amplified decrease in I_C. In effect, the decrease in I_C compensates for the increase in load current so as to maintain the same voltage drop across R1. We see, then, that any change in V_R is counteracted to regulate the voltage. Assume that the load current decreases, and reason through the regulating action that results.

5-16. Now consider what takes place if V_U were to rise. Wouldn't I_B increase and cause the transistor to conduct more heavily? Because the transistor conducts more heavily, the current through R1 must increase. Practically all of the rise in V_U is therefore dropped across R1, and V_R remains practically the same. For a decrease in V_U, the reverse action occurs.

5-17. Another circuit possibility is that shown in figure 16,B. The emitter is kept at a constant potential by the Zener diode. Thus, any voltage variation appearing across the output terminals is sensed by the transistor's base as an input signal. Again we have amplifier action, and the current through the transistor changes to regulate the output voltage, V_R.

5-18. An advantage of this circuit is that V_R can be adjusted to a desired fixed level. This feature makes it possible to set V_R at a higher or lower value to compensate for aging or for

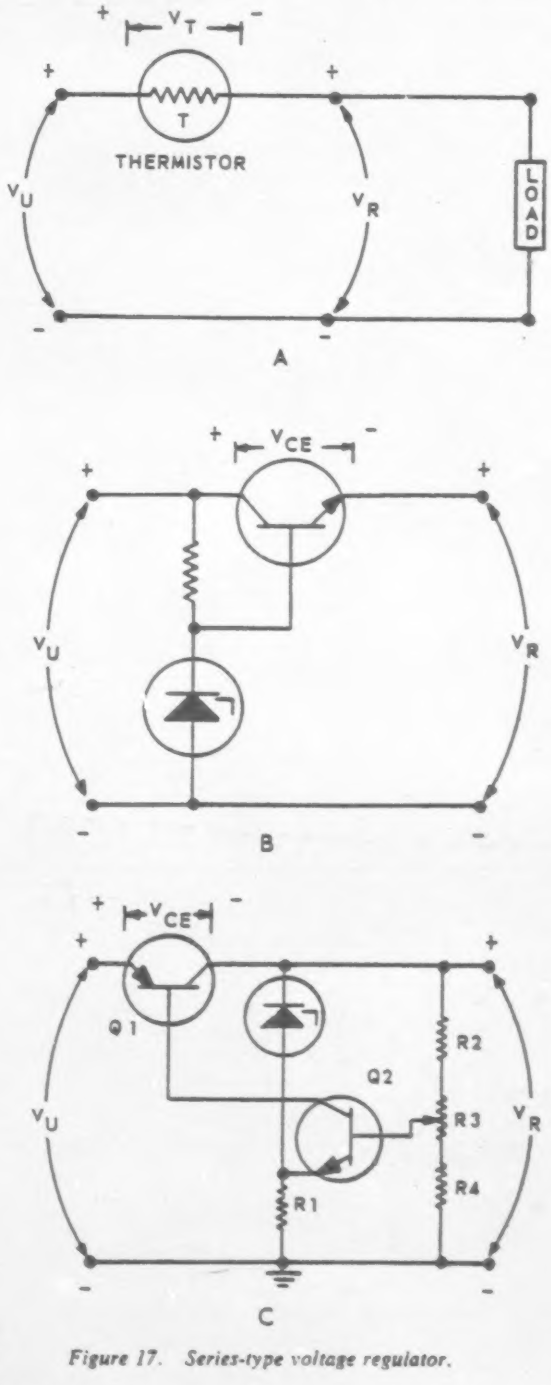


Figure 17. Series-type voltage regulator.

different load requirements. Resistors R2 and R4 establish the range of voltage for bias that can be tapped off R3. The bias determines the transistor's quiescent (operating) point and its d-c resistance. In other words, by changing the bias setting, we change the transistor's resistance so that a greater or lesser amount of the input voltage appears at the output terminals. For instance, to increase the d-c output voltage, V_R, the movable contact to R3 must be moved downward. This will decrease the forward bias on the n-p-n transistor. Since the transistor conducts less current, less current flows through R1, which means the voltage drop across R1 is decreased. Accordingly, the output voltage, V_R, is increased. From the viewpoint of voltage division, we have simply increased output resistance by decreasing the transistor's forward bias. Proportionately more of the applied input voltage is therefore "seen" at the output terminals. To obtain a lower value of regulated voltage, V_R, of course, the movable contact is moved upward (more positive) to increase the transistor's forward bias.

5-19. A Zener diode does not need a "starting" voltage surge; therefore, it does not require the associated circuitry necessary to ionize a VR tube.

5-20. A drawback of any shunt type regulator is its low efficiency. We can appreciate this when we realize that the output power is divided between the load and the shunting circuit; at no-load the shunting circuit dissipates the full output power. Consequently, proportionately large amounts of output power are wasted, particularly when the loads are small. For this reason, the small-load efficiencies of shunt regulators are notably low.

5-21. *Series voltage regulator.* A series type regulator can have comparatively high small-load efficiencies. That is because, as its name implies, the regulating device (a variable resistance) is in series with the load. In figure 17,A, we see how a thermistor is used to prevent voltage changes caused by variations in load. The thermistor acts as a variable resistor in a voltage divider circuit. If the load resistance decreases, tending to lower V_R, the resistance of the thermistor decreases as a result of the additional heating caused by the increased load current. This action keeps the ratio of the thermistor's resistance and load resistance about the same. Since the voltage division of the input is virtually unchanged, V_R is regulated. When a decrease in load occurs, the thermistor's resistance increases to regulate V_R.

5-22. Although a thermistor regulates fairly well under changing load conditions, it will not regulate input variations. In fact, it makes regulation worse instead of better. Assume that the input V_U increases. What happens? Current increases, causing the drop across the thermistor to decrease. This is just the opposite of what we want. The drop across the regulating device should increase to prevent a rise in V_R.

5-23. A series-regulator circuit that regulates both load and input variations is shown in figure 17,B. Moreover, the transistor's amplifying capability improves regulation. The n-p-n transistor is a sensitive variable resistance. Because its base is held at a fixed potential by the Zener diode, any change in V_U or V_R affects the transistor's bias. The drop across the transistor, V_{CE}, changes to stabilize V_R. Let us briefly describe how the circuit operates.

5-24. Consider first a change in load. We will assume that it increases. This tends to lower V_R and increase the potential difference between the emitter and base. Since the base-to-emitter forward bias is increased, the transistor conducts more heavily. Therefore, V_{CE} is lowered and counteracts the decrease in V_R. So we have regulation. If the load decreases, the bias decreases to regulate V_R. In a similar fashion any variation of the input V_U causes a bias change. The drop across the transistor automatically increases if V_U increases, or decreases if V_U decreases. Such action maintains V_R nearly constant. Be sure you understand why this is so. Study figure 17.B, and determine the sequence of events for all the possible conditions of change.

5-25. We can get better regulation by using a circuit such as the one shown in figure 17,C. Note the Q1 is a p-n-p transistor, whereas Q2 is a n-p-n transistor. Inasmuch as each transistor amplifies, this arrangement is quite sensitive and can give excellent output-voltage stability over the designed range. Observe also that the output of this circuit can be adjusted by R3, as explained earlier.

5-26. After we go through one condition of change you should be able to analyze the performance of the circuit for the remaining three. We will describe the behavior of the circuit for the condition of increased load. This leaves the conditions of decreased load, increased input V_U, and decreased input V_U for you to figure out.

5-27. To prevent V_R from dropping with an increase in load, V_{CE} of Q1 must decrease. Let's keep this in mind and see if it will occur. Any decrease in V_R is felt in full at the emitter of Q2, but is felt only in part at the base of Q2. Here's why: Since the drop across the Zener diode is constant, any voltage change appears entirely across R1, from the emitter of Q2 to ground. However, this is not so for the base of Q2. It "sees" only a fractional amount of the change which is tapped off of R3 in the voltage divider circuit (R2, R3, and R4). You recall that for an n-p-n transistor the base is more positive than the emitter. Then if the emitter drops more (becomes less positive) than does the base, the bias increases. Such being the case, Q2 conducts more heavily. Note that the collector current of Q2 is actually the base current I_B of Q1. We know, then, that an increase in I_B of Q1 causes Q1 to conduct more heavily and its V_{CE} to drop accordingly. Isn't this what we wish to happen?

5-28. From the standpoint of bias on Q1, its base becomes less positive (more negative with respect to its emitter) because Q2 conducts more heavily. Since Q1 is a p-n-p transistor, the bias increases and causes the voltage V_{CE} across Q1 to drop as in our previous analysis.

5-29. However you choose to analyze the circuit, the outcome will be the same: regulation.

5-30. Let us now look at a more complex voltage regulator which is similar to a type you may have to maintain. Note in figure 18 that Q5, Q6, and Q7 are connected in parallel; they serve as series-regulating transistors in the negative line of the supply. These transistors are controlled by the amplifying network which includes Q1, Q2, Q3, and Q4. The transistor Q1 senses any voltage change at its base since Zener diode Z1 keeps Q1's emitter voltage constant. The amplified change becomes inverted at Q1's collector and appears on the base of Q2. Another amplified inversion occurs at the collector of Q2 which is also the base input to Q4. The amplifier circuit containing Q3 is a regenerative feedback arrangement which increases the input change to the base of Q4. To understand this, observe that a double inversion is realized in going from the base of Q4 to the collector of Q3; one inversion occurs from base to collector of Q4 and another from emitter to collector of Q3. Because this is a regenerative loop, the capacitor is used to prevent high-frequency oscillation. Any spurious high frequency is shunted by the capacitor across Q3; since there is no inversion across Q3, the feedback loop for high frequencies is degenerative. Zener Z2 establishes the reference for Q3, and amplifier operation is adjusted to the optimum condition with the variable emitter resistor (this is a factory adjustment and normally need not be made again).

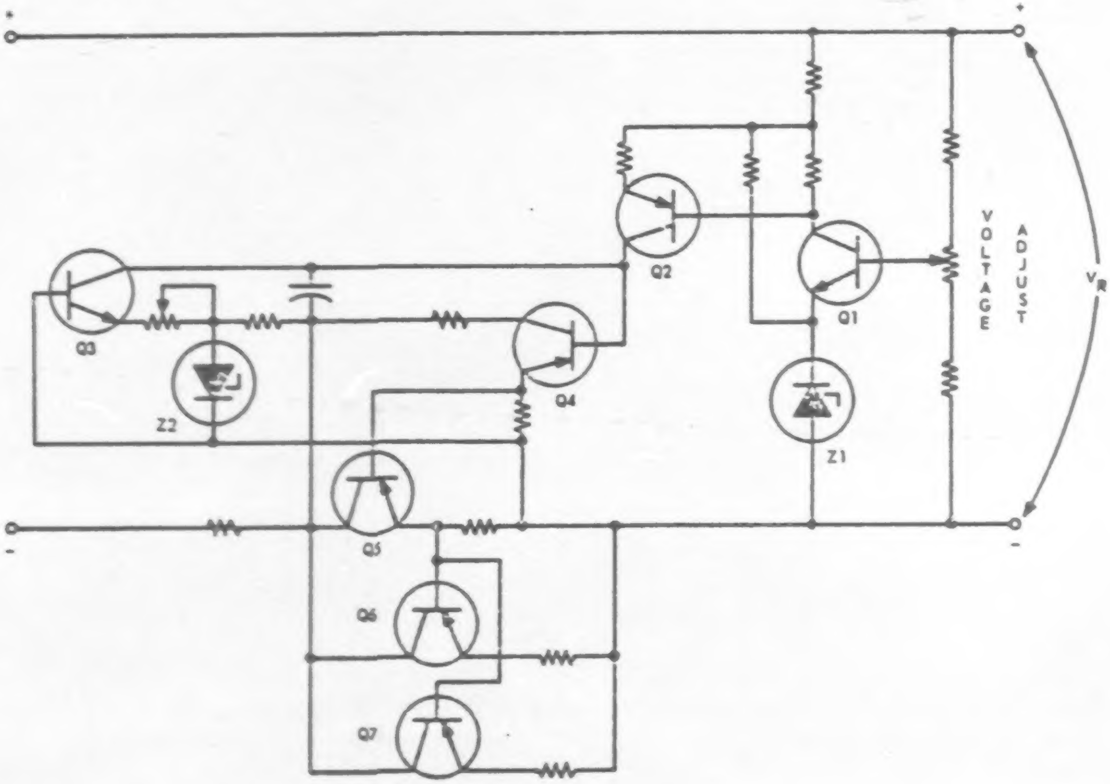


Figure 18. Complex series voltage regulator

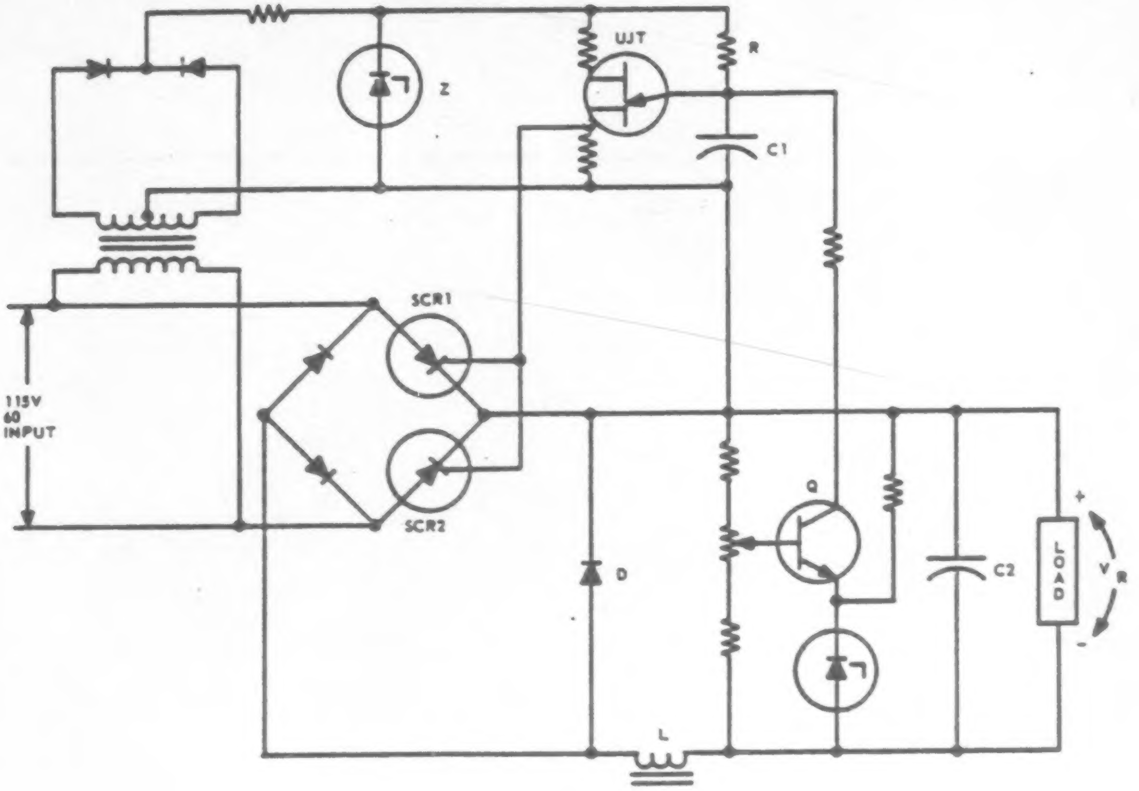


Figure 19. Switching-type voltage regulator.

5-31. The output of Q4 is taken from its emitter, so the output is in phase with the change applied to its base. This output controls Q5 which in turn controls the other two paralleled series-regulating transistors Q6 and Q7.

5-32. As in previous circuits, we will assume a particular condition and determine the regulating action that results. Let us suppose that the regulated voltage V_R tends to rise (become more positive). To counteract this, the voltage drop across Q5, Q6, and Q7 must increase. We will see whether this occurs.

5-33. If V_R increases, the base of Q1 goes more positive. Since it is an n-p-n transistor it conducts harder and its collector becomes less positive. This makes the base of p-n-p transistor Q2 less positive, which causes it to conduct harder also. Consequently, the collector of Q2 and base of Q4 become more positive. The circuit containing Q3 regeneratively feeds back the collector output of Q4 to drive the base of Q4 even more positive. (You should be able to figure out why this is true.) Because the base of Q4 goes more positive, so must its emitter. This action decreases the forward bias on p-n-p transistor Q6, thereby causing it to conduct less. The reduced voltage drop across the emitter resistance of Q5 decreases the forward bias applied to the bases of Q6 and Q7. We note, therefore, that Q6 and Q7 conduct less, as does Q5. The result is that the voltage drop increases across these three regulating transistors. This is what we said should occur to counteract the assumed increase in V_R. If V_R would try to decrease, the opposite actions would occur. Regulation is excellent because this circuit is highly sensitive and reacts instantly to prevent variations in output voltage caused by load or input.

5-34. *Switching regulators.* Besides the various types of shunt and series voltage regulators, there are switching regulators that have operating efficiencies approaching 100 percent. These regulators use semiconductor switching devices such as unijunction transistors (UJT) and silicon control rectifiers (SCR) in a variety of control circuits.

5-35. The switching regulator circuit shown in figure 19 is unique in several respects. Notice that the SCR's are part of the rectifying bridge circuit. Regulation is accomplished by controlling the firing point of the SCR's. An SCR is similar to a thyratron, but its forward drop and turn-off times are about one-tenth those of a thyratron. As much as 50 amperes can be handled by high-current SCR's. The SCR's in this circuit are fired by gate pulses which are developed when the UJT conducts. The time relationship of the gate pulses to the start time of each 115-a-c input alternation determines the conducting time of the SCR's (see fig. 20). By sensing load voltage variations, the gate pulses are electrically delayed or advanced to adjust the conduction time of the SCR's. This effectively delivers the proper amount of current to C2 so that it maintains a virtually constant charge voltage which is V_R. Because a choke input filter is used, the diode D is needed so that current can continue to flow through the choke L and load when both SCR's are cut off.

5-36. To understand how the gate pulses are produced, study the upper circuit shown in figure 19. The output from the full-wave center-tap rectifier is clipped by Zener diode Z. This clipped waveform appears across the UJT circuit and also across R in series with C1. The UJT acts as a switch; it does not conduct until the emitter reaches a prescribed potential. When the applied voltage rises to its clipped value, C1 charges to the emitter potential which fires the UJT. After discharging C1, the UJT cuts off. This on-off action of the UJT once per alternation of the input produces the gate pulses that are applied to the SCR's. Whichever SCR has the forward-biased anode at the time a gate pulse occurs will fire; thus, the SCR's fire alternately (see fig. 20).

5-37. Since the time at which a gate pulse is generated depends on the charge time of C1, the

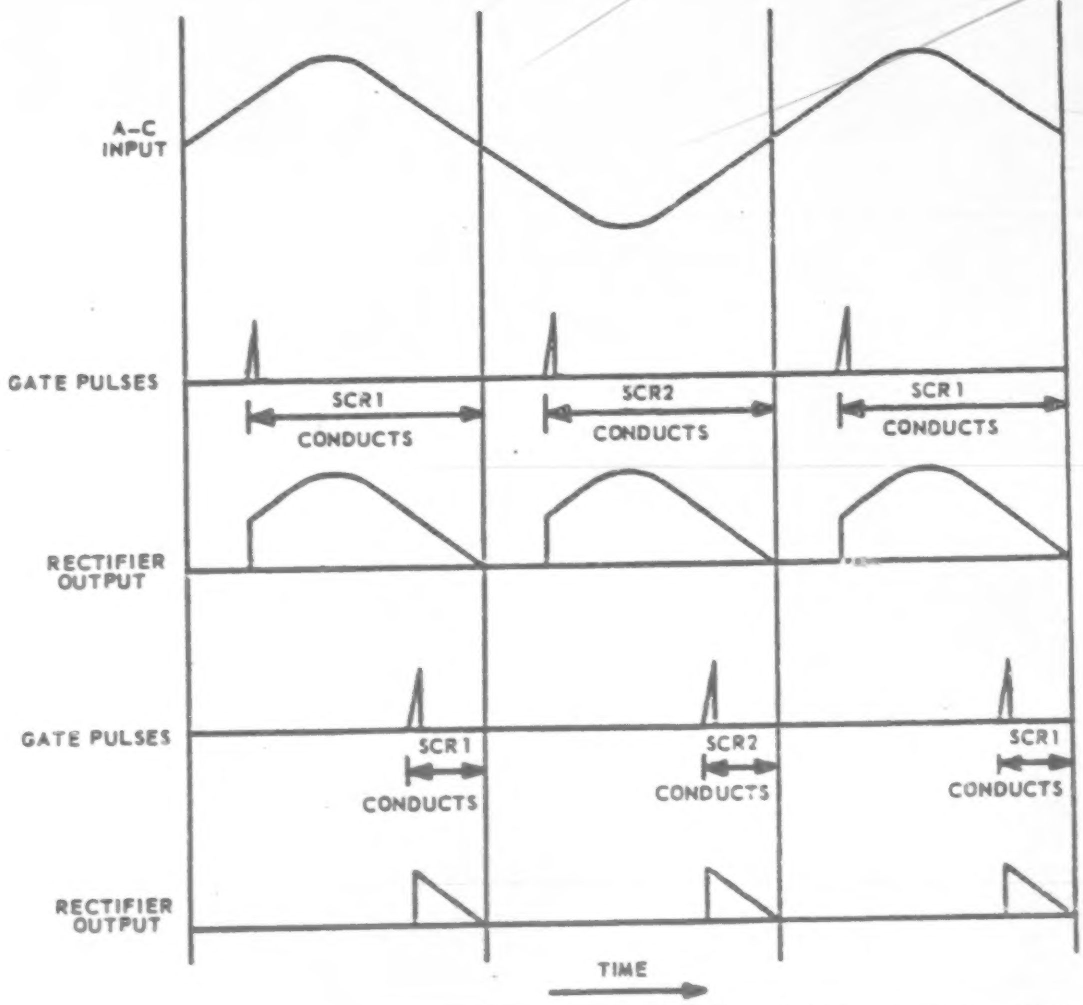


Figure 20. Waveforms for switching voltage regulator.

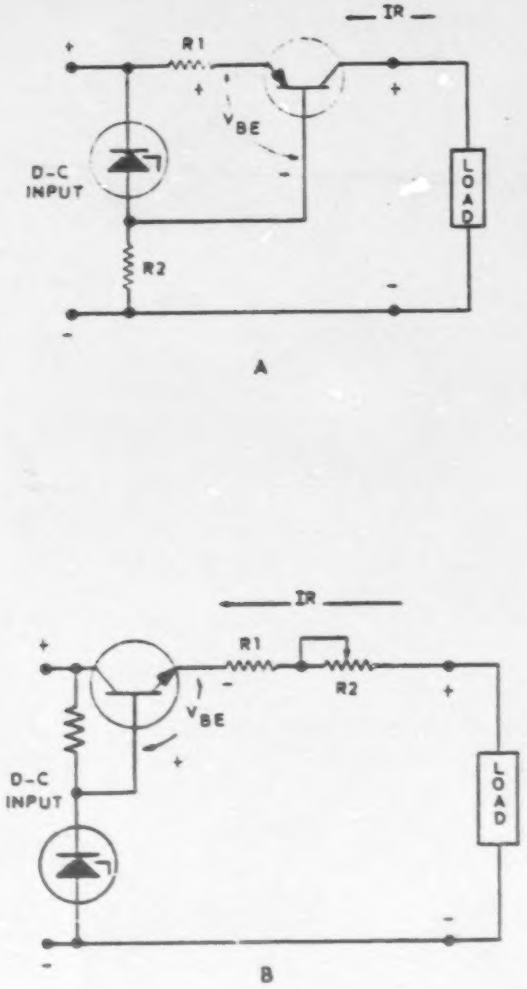


Figure 21. Constant-current regulators.

gate can be delayed or advanced by increasing or decreasing the charge time, respectively. This is done electrically by the circuit containing n-p-n transistor Q. For example, if the voltage V_R tends to rise, a positive error voltage, sensed at the base of Q, causes Q to conduct harder. Thus, current is diverted from C1 and its charge time is increased. As a result, the gate pulses are delayed. From figure 20 you see that the SCR's conduction time is decreased. This reduces the charge on C2, thereby counteracting any increase in V_R. On the other hand, if a change in load or input tends to decrease V_R, the gate pulses are advanced. The SCR's conduct longer, and C2 charges more to regulate V_R. Determine why this occurs and you will understand how this regulator maintains a constant voltage output under varying load or input conditions. •

5-38. **Constant-Current Regulators.** In contrast with a voltage regulator, the current regulator stabilizes output current, I_R, rather than output voltage, V_R. Its primary function is to supply a constant current to the load. To do this, the regulating device must prevent a change in output current.

5-39. Figure 21,A, shows a circuit that can be used. Instead of sensing the voltage across the output terminals, the transistor senses the current through R1. Any current change develops a voltage change across R1, which alters the bias of the p-n-p transistor. The transistor resists the current changes. For example, an increase in current will increase the voltage across R1 and make the emitter less positive. This decreases the base-to-emitter forward bias of the p-n-p transistor and decreases the current flow through it. Thus, the transistor action opposes any change in I_R.

5-40. The circuit shown in figure 21,B, has the added feature of adjustment by R2. Note that it uses an n-p-n transistor, and the sensing resistors R1 and R2 are on the load side. Although this circuit is somewhat different, it regulates I_R in much the same manner as the one previously described. Suppose, again, I_R tries to increase. The emitter becomes more positive and the base-to-emitter forward bias of the n-p-n transistor decreases. This means that the increase in current is opposed by the transistor action. On the other hand, if I_R tries to decrease, the base-to-emitter bias increases. Since any change in current affects the bias, the transistor counteracts the change and thereby regulates the output current.

5-41. Improved regulation is achieved by amplifying the error applied to the control transistor. This is illustrated in figure 22. The transistor Q2 serves as a d-c amplifier. Output current can be adjusted to the desired value with R2. Otherwise, this circuit corresponds to the circuit shown in figure 21,A, and regulates in the same manner.

5-42. **Symptoms and Troubles.** Aside from the use of solid-state devices in place of electron tubes, circuit configurations for solid-state power supplies have been shown to be similar or identical to electron-tube power supplies. For this reason, troubleshooting procedures are practically the same with regard to circuitry. Often the malfunction of a power supply is the fault of the rectifying device. Electron-tube diodes fail; so also do metallic and crystal rectifiers. Certain faults can be attributed directly to the rectifier: (1) open-circuited rectifier, (2) short-circuited rectifier, (3) high forward-voltage drop, (4) high leakage current, and (5) overheated

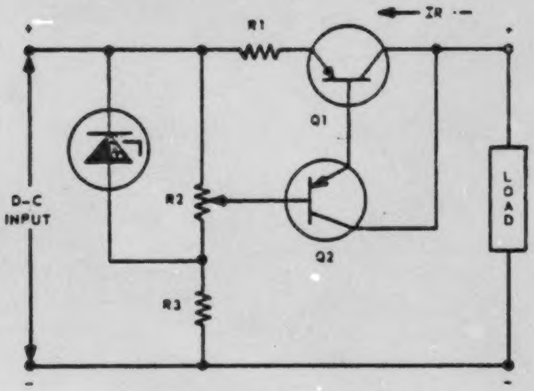


Figure 22. Constant-current regulator with d-c amplifier.

rectifier. The symptoms associated with these faults can be readily detected, since they cause obvious and sometimes serious trouble.

5-43. An open-circuited rectifier causes a lower d-c output or no d-c output. If the rectifier unit is a full-wave or polyphase type, the d-c output would be reduced when one rectifier is open-circuited. If it is a single-phase half-wave rectifier, there will be no d-c output.

5-41. Improved regulation is achieved by amplifying the error applied to the control tran-circuited rectifier. In addition, there will be excessive heating and a-c will appear at the output. Unless short-circuit protection is built into the power supply, other circuit components can be permanently damaged.

5-45. For a solid-state rectifier, either a high forward-voltage drop or a high leakage current will cause lowered d-c output and increased heating. A high forward-voltage drop is caused by an increased forward resistance, whereas a high leakage current is caused by a decreased reverse resistance. Whichever fault occurs, the rectification ratio is reduced accordingly, and likewise the efficiency of the rectifier.

5-46. An overheated rectifier may be caused by faults (2), (3), or (4) mentioned previously, and also can be caused by excessive loading or inadequate cooling. Regardless of the cause, a rectifier that is heated beyond its safe limits will be short-lived or completely destroyed. When the source of the trouble is the rectifier itself, replacement of the rectifier will return the circuit to normal operation. However, when the overheating is the result of loading or improper heat dissipation, the trouble will persist after the rectifier has been replaced, unless corrective measures are taken to insure proper loading and cooling.

5-47. When a power supply has a regulator unit, a defective solid-state device (thermistor, Zener diode, transistor, etc.) may be the source of trouble. The symptoms will range from an increased or reduced d-c output (regulated or not) to no d-c output. The symptoms and troubles are dependent upon the complexity of the circuitry as well as the type of regulator unit employed. We cannot, therefore, speak on this subject in a general manner. For any particular unit, you will have to depend on your basic knowledges and reasoning ability to determine the cause of a malfunction. To give you some practice, we will describe symptoms and diagnose specific troubles in one of the circuits just studied.

5-48. If the output voltage of the regulator in figure 18 is abnormally high and unregulated, the trouble will likely be in the circuit of Q1. Because there is no regulation, we know Q1 is not functioning properly. Moreover, we can reason that the collector voltage of Q1 must be high to cause a high output voltage. Three troubles that can give these symptoms are: (1) an open between the Voltage Adjust and + output terminal; (2) an open transistor, Q1; and (3) an open Zener diode, Z1. For each of these troubles the series-regulating transistors Q5, Q6, and Q7 will have an abnormally high forward bias. Therefore, practically all of the d-c input V_I is "seen" as unregulated voltage at the output of the regulator. Be certain that you understand why the troubles specified can give the symptoms described. This may require your restudying the regulating principles involved.

6. High-Voltage Power Supplies

6-1. By means of a step-up single-phase or polyphase transformer, a-c voltages can be increased to the necessary levels to obtain desired rectified high voltages. The high d-c voltages required for TV equipments are in the order of thousands of volts. For high-power equipments such as those needed for broadcasting, the high-voltage (HV) supply must deliver considerable

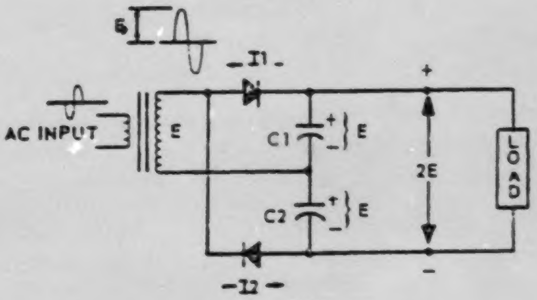


Figure 23. Conventional voltage doubler.

current. Such supplies use the same full-wave single-phase and polyphase rectifier circuits that we discussed in the preceding section. Of course, the input transformers must step up the voltages to the required peak values, and components must be rated to handle high voltages and currents. Like low-voltage power supplies, tube and solid-state rectifiers are used.

6-2. Since high-power HV supplies do not differ in operating principles from those just studied, we will give our full attention to various types of low-power HV supplies that are found in TV equipments. Although these HV supplies develop 20,000 volts or more, load current is relatively small. We will explain how such outputs can be obtained by voltage multipliers and by rectification of pulses or an oscillating voltage.

6-3. Usually the a-c source and d-c load are sufficiently stable so that regulation is not necessary. However, a regulated high voltage is required for some applications. Therefore, we will analyze circuits which keep the voltage output constant under varying load conditions. The final portion of this section is given to diagnosing troubles from given symptoms.

6-4. **Voltage Multipliers.** If a voltage multiplier is used, it is not necessary that a transformer step up the a-c voltage to as high a value. In fact, a high d-c voltage can be developed by voltage multiplication without a transformer at all. Let us review two types of rectifying circuits that produce a d-c output voltage which is about twice the peak a-c input voltage; then we will explain how higher multiples of voltage can be developed from a given source.

6-5. *Conventional voltage doubler.* In figure 23 the rectifiers are connected so that they conduct forward current on alternate half-cycles. During the positive alternations of the secondary voltage, the upper rectifier conducts I1, and the capacitor C1 charges to the peak secondary voltage E. During the negative alternations of the secondary voltage, the lower rectifier conducts I2 and the capacitor C2 charges, also to the peak secondary voltage E. Since the polarity of the charge on C2 is series-aiding the charge on C1, the voltage across the output terminals is 2E (approximately 2.8 times the secondary rms voltage). Inasmuch as both the charging (via the rectifier) and discharging (via the load) of C1 and C2 constitute the ripple, the ripple frequency is twice the frequency of the input a-c. This doubler is essentially a full-wave rectifier; both the positive and negative alternations feed power to the load.

6-6. A disadvantage of this circuit is that the input and output are at different d-c voltage levels. If the lower output terminal is grounded, the lower end of the secondary is E volts d-c above ground. On the other hand, if one side of the input is grounded (as will necessarily be the case for a-c taken directly from a power line), neither of the output terminals can be grounded.

6-7. *Cascade voltage multipliers.* A circuit that permits one side of both input and output to be grounded is shown in figure 24. Moreover, by adding sections (the heavy-lined circuitry in figure 24,B), any desired multiplication of voltage can be obtained. After we analyze the operation of the cascade doubler, we can readily explain how higher degrees of multiplication are acquired.

6-8. For convenience, let us consider the negative alternations first (see fig. 24,A). During these alternations, CR1 keeps C1 charged to E (about 1.4 rms), with a polarity as indicated in the figure. On the positive alternations, C2 is kept charged by the conduction of CR2. When CR2 conducts (forward direction), C2 "sees" the peak a-c input voltage which is series-aiding the voltage across C1. Thus, the input peak E plus the voltage E on C1 charges C2 and 2E.

6-9. Although full-wave rectification occurs, the output capacitor C2 is charged only during the positive half-cycle. Consequently, the ripple

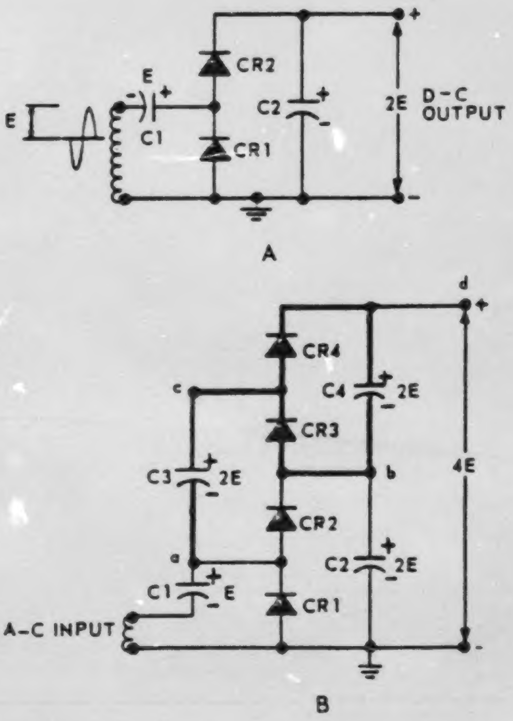


Figure 24. Cascade voltage doubler and quadrupler.

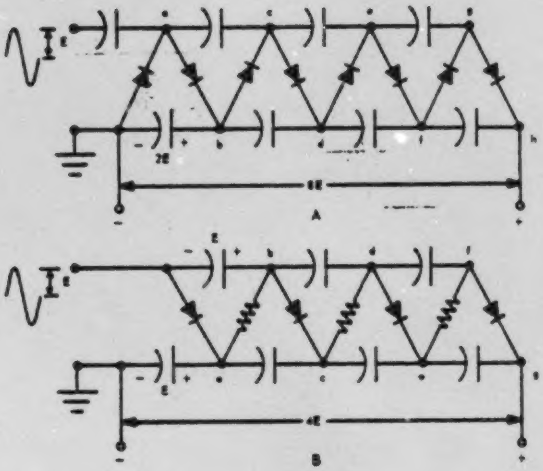


Figure 25. Cascade voltage multipliers.

frequency of the cascade doubler is that of a half-wave rectifier, equal to the a-c input frequency. This means that, like the half-wave rectifier, the cascade doubler is not suited for heavy loads. Regulation is poor and filtering is difficult.

6-10. For light loads that require a high d-c voltage, the cascade circuit is quite popular, since it can be built up to provide the desired level of output. Refer to figure 24,B, and note that the heavily lined circuitry is a replica of the cascade doubler circuit. It is therefore possible to increase the d-c voltage in multiples of two by adding on doubler circuits.

6-11. The lightly lined circuit of figure 24,B, is identical to that of figure 24,A, and operates in the same manner. The heavily lined circuit differs only in that the voltage across the input capacitor C3 is 2E rather than E. Capacitor C3 is kept charged to 2E by the action of CR1 and CR3. These two rectifiers effectively place C3 in parallel with C2. Whenever the charge on C3 is less than that of C2, CR3 is forward biased. So when CR1 becomes forward biased during the negative half-cycle of the source a-c input, C3 is charged by C2. We see, therefore, that the output capacitor C2 feeds the input capacitor C3.

6-12. Note that the d-c voltage with respect to ground (or common) at point a is E, at point b is 2E, at point c is 3E, and at point d is 4E. Additional sections will give 5E and 6E, 7E and 8E, and so on. Figure 25,A, shows how the circuit may be represented schematically.

6-13. A similar cascade voltage multiplier circuit is illustrated in figure 25,B. For the same number of sections, however, only half of the value of d-c voltage is developed. Resistors are used to replace the diodes that conduct during the negative input alternation. Each resistor permits the upper-line capacitor to charge through the a-c source to the potential of the lower-line capacitor. Observe in figure 25,B, that the upper-line and lower-line capacitors in the first section (likewise, in subsequent sections) are charged to the peak input a-c. This multiplier draws source current only on the positive input alternation. As a quadrupler, it requires three resistors and three more capacitors than the circuit of figure 24,B.

6-14. Either type of cascade voltage multiplier is particularly useful as a high-voltage low-current supply. Tube, metallic, or crystal rectifiers can be used. Each rectifier must withstand twice the peak input a-c in the reverse direction. Regardless of the amount of multiplication, the maximum PIV on any single rectifier is 2E. Make sure you understand why this is true. Also prove to yourself that the ripple frequency is the same

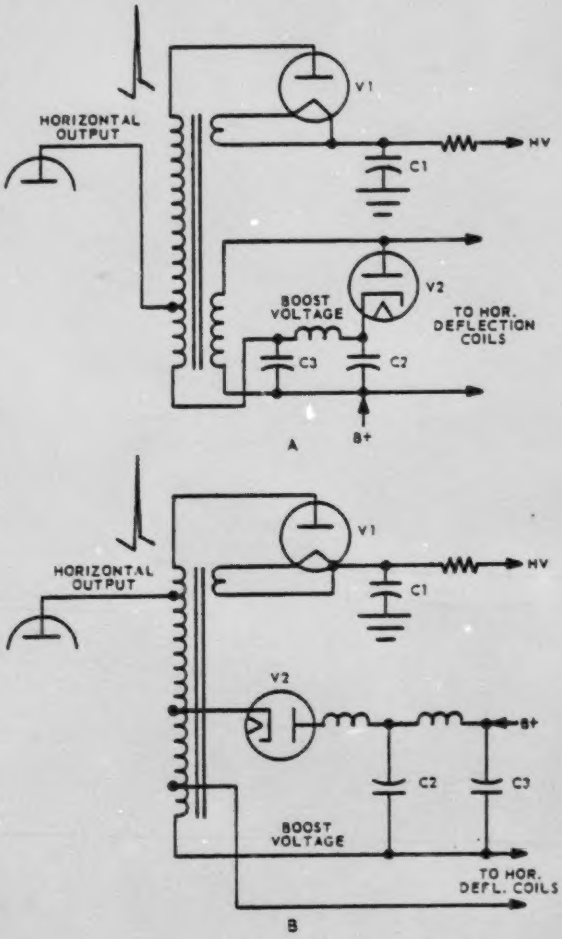


Figure 26. Flyback HV system.

as the input a-c regardless of the amount of multiplication.

6-15. **Pulse and Oscillator Types.** Although a high-voltage transformer can be excited by the 115-volt a-c line, it is more practical to use a pulse, an oscillating, or a transient voltage for excitation when the high-voltage d-c load is small. You know, for example, that the high-voltage supplied to a picture tube is commonly excited by the horizontal output stage in a TV receiver. The current drain, which is less than 1 ma, does not adversely affect the operation of the stage.

6-16. After briefly discussing flyback pulse-type high-voltage supplies which should be familiar to you, we will analyze the operation of somewhat more complex supplies which incorporate regulating circuitry.

6-17. *Flyback HV system.* The circuits shown in figure 26 are representative of HV supplies that are pulsed by the horizontal output amplifier. Both systems employ autotransformer action to produce a high-voltage spike during the flyback time of the horizontal sweep. This short-duration pulse applied to rectifier V1 keeps C1 charged to provide a high d-c voltage output. Because the ripple frequency is that of the horizontal sweep (usually 15,750 cps), filtering is readily accomplished with a small capacitor (about 500 μμf).

6-18. Although different flyback transformers are ~~employed,~~ both systems develop a boost voltage. The diode V2 (damper for the horizontal deflection coils) provides rectification of the flyback overshoot pulse, thereby charging C2 and C3 to a higher than B+ d-c voltage. This boost voltage is usually applied to the plate of the horizontal output tube and may also be applied to other circuits.

6-19. A definite advantage of the flyback HV system is its dependency upon the horizontal output for excitation. If there is no horizontal output, there is no high voltage. Thus, a failure in the horizontal output removes the high voltage from the picture tube. This prevents a stationary spot from appearing on the screen which may burn or desensitize it.

6-20. *Regulated HV systems.* As mentioned earlier, most HV systems do not need to be regulated. Nevertheless, it is well that you understand how regulation is obtained when required. The two systems that we have selected to explain operate on different principles. Unlike the flyback pulse type, both are excited with oscillators which are regulated by sensing-error voltages in the HV output.

6-21. The system shown in figure 27,A, is made up of a high-frequency oscillator, conventional voltage doubler, and voltage divider arrangement that amplifies any error voltage developed across R1. We have drawn the circuit of V1 so that you can readily recognize it as a Hartley type oscillator. The oscillating signal is impressed across the primary of the transformer, T. Now trace through the circuit containing the transformer's secondary, V2, V3, R1, C3, and C2. Compare this circuit with that of figure 23 and you will see that it is essentially the same. The resistor R1 is needed to develop a bias for V4. Moreover, it is across this resistor that any change in the HV output is sensed and coupled to the grid of V4. The circuit containing V4 and V5 operates as a variable voltage divider that adjusts the screen grid potential of V1. A change in screen grid potential changes the amplification factor of V1 and therefore the amplitude of the oscillating signal. Since this signal is the excitation to the HV rectifiers, any change in its amplitude affects the high-voltage d-c output.

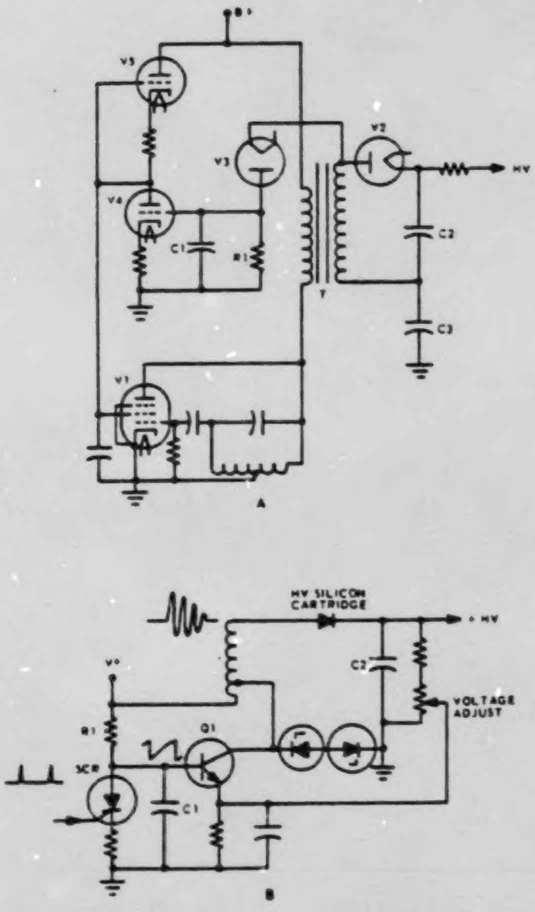


Figure 27. Regulated HV power supply.

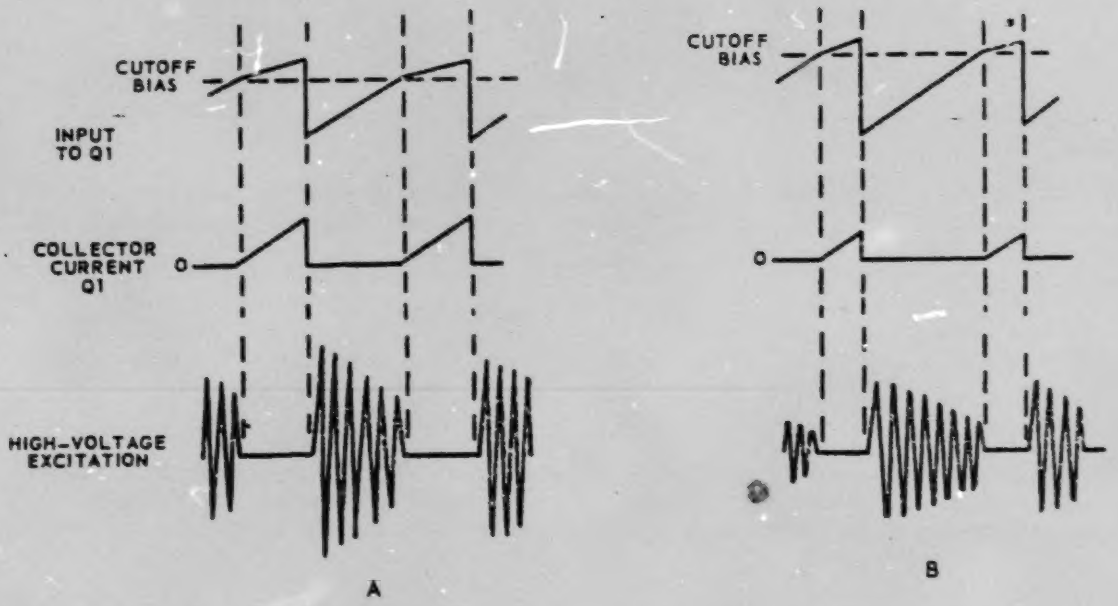


Figure 28. Waveforms associated with figure 27, B.

6-22. Now let's look at specific cases. Assume a load variation that would tend to change the HV output. Suppose load current increases. The HV would tend to drop because C2 and C3 deliver more current. This means that V2 and V3 pass more current and the average current through R1 increases; capacitor C1 acquires a more negative charge. With increased bias applied, V4 conducts less, thereby decreasing the bias on V5. Thus, the voltage at the plate of V4 rises, applying a more positive potential to the screen grid of V1. Since this increases the amplitude of the oscillating signal generated, excitation is increased to counteract the drop in HV caused by loading. Opposite actions would occur if the HV tended to rise.

6-23. Excellent regulation is achieved because the error voltage is amplified by both V4 and V5 in the voltage divider circuit. Thinking of this circuit in terms of resistance, note that when the error makes the resistance of V4 increase, there is an immediate resistance decrease of V5. Conversely, a resistance decrease of V4 causes a resistance increase of V5.

6-24. Because excitation is obtained from a free-running oscillator, provision should be made to remove high voltage from a picture tube or camera tube when there is sweep failure. Such protection is not needed, however, if a driven oscillator is employed. The system shown in figure 27,B, contains such an oscillator. Transistor Q1 is driven "on" and "off" by the input signal applied to its base (see fig. 28,A). Each time Q1 cuts off, the auto transformer is shock-excited and oscillates as illustrated at its natural resonant frequency. As soon as Q1 is driven into conduction, however, the oscillations cease. You need bear in mind that there is no HV excitation when Q1 is "on."

6-25. The operation of this system is normally dependent upon positive trigger pulses which gate the SCR. It is so designed that the SCR will not fire unless gated. Since the positive triggers which gate the SCR are obtained from the horizontal output (flyback pulses), the system becomes inoperative when there is no horizontal output. To clarify this, we will assume that no input triggers are present and will determine the condition of the system. With the SCR off, C1 charges and Q1 is forward biased. As pointed out, when Q1 is conducting there are no oscillations; therefore, there is no HV output. The system will stay this way indefinitely.

6-26. Now let us apply a positive input trigger. Once the SCR is gated, C1 rapidly discharges; this reverse biases Q1. Because Q1 cuts off, the transformer is shock excited and C2 is charged via the rectifying diode to develop an HV output. After C1 has discharged, the SCR cuts off and C1 again charges to the bias which causes Q1 to conduct. Transistor Q1 remains conducting until another trigger fires the SCR and the cycle is repeated.

6-27. If you understand what has been said so far, you will easily follow our explanation of how this system regulates its HV output. We will assume the HV output tries to increase. Observe in figure 27,B, that the increase is sensed on the emitter of Q1. Since the emitter is made more positive, the base must have a higher potential before Q1 will conduct. Such being the case, C1 will charge to a higher potential. Note in figure 28,B, that this effectively reduces the conduction time of Q1. Because the amount of primary current is likewise reduced, the amplitude of excitation is decreased as illustrated. The decrease in excitation counteracts the HV increase and therefore regulates the system. The opposite actions occur when the HV tends to decrease. It will benefit you to figure this out. You should also determine how the voltage adjust potentiometer affects the system.

6-28. We need to mention that the Zener diodes are connected in series from the collector of Q1 to ground as a protective measure. Upon cutoff, the collector voltage rises and falls sharply to values that may exceed the transistor's maximum rated inverse-peak or punch-through voltage. These Zener diodes have breakdown voltages below the transistor's maximum rated values; therefore, they shunt damaging positive or negative pulses to ground.

6-29. **Symptoms and Troubles.** Many of the symptoms and troubles found in HV power supplies are similar to those discussed for low-voltage supplies. However, troubles related to high-frequency excitation have symptoms peculiar to an HV system. To bring this to your attention, let us cite specific symptoms and determine, as previously done, the possible trouble or troubles.

6-30. Suppose the kinescope suddenly goes blank, the picture and raster disappear. Since the kinescope needs high voltage to have a raster, we can reasonably suspect that the trouble may be in the HV supply. Quick visual checks should be made, however, before investigating the HV circuits. The filaments of the kinescope, the tubes in the low-voltage power supply, and those in the horizontal circuits should be checked to determine that they are lit. Unless the tubes in the horizontal circuits are lit, the HV circuit will not have excitation. Assuming that all is well up to this point, let us look into the HV system. If the damper diode and HV rectifier are tubes, both should be lit. Ordinarily, since the HV rectifier tube obtains its filament voltage from the flyback transformer (see fig. 26), a lit rectifier tube indicates that excitation is present.

6-31. Having completed the visual checks, turn the equipment "off" and discharge the high-voltage supply. Ohmmeter readings can now be taken to check the high-voltage fuse and the resistor in the HV lead and to make continuity checks. An open in the HV circuit, of course, will give the symptoms previously described.

6-32. If ohmmeter checks reveal that nothing is wrong, voltmeter readings may indicate the trouble. Do not attempt to measure the high voltage unless special high-voltage probes are used. Even lit tubes can be defective. As you know, you must substitute or check the tubes when voltage readings are abnormal.

6-33. Certainly, there may be variations in the sequence of checks, but sound thinking based on the symptoms observed is important. This cannot be done unless you have a thorough knowledge of the operating principles of HV power supplies. It is evident that a symptom or set of symptoms can be caused by many types of troubles.

6-34. In a regulated HV system, symptoms can point to a specific type of trouble. For example, suppose the HV of the circuit in figure 27,A, is unstable and lower than normal. The fact that it is unstable immediately points to the sensing circuit because changes in the HV load are not being regulated. Furthermore, since the HV is lower than normal, we can reason that the output of oscillator V1 is below normal. Let us consider a trouble in the sensing circuit that will cause these symptoms.

6-35. Suppose C1 is shorted. There will be neither a bias nor an error voltage developed on the grid of V4. Because the grid of V4 is at ground potential, the plate voltage of V4 will be low. Consequently, there is a lower voltage applied to the screen grid of V1. This causes an abnormally low oscillator output amplitude and accounts for a decreased HV. So we see that when C1 is shorted, the symptoms described will occur.

CHAPTER 3

Sync Generators

THE SYNC GENERATOR establishes the TV pulse rates; therefore, it is often called the heart of a TV system. It can also be considered the nerve center since its signal-generating and waveshaping circuits control the timing sequence that governs the operation of the entire system. Such vital functions should be well understood by maintenance personnel. To further your knowledge of the operating principles involved, we have selected various types of sync generators for study in this chapter. We progress from a simple noninterlace type to the more complex interlace types.

2. Many of the circuits are basic ones that were analyzed in your previous training; therefore, our analysis will, for the most part, be based on block diagrams. Only special circuits will be discussed in detail. Our objective is to enable you to analyze the operation of a variety of sync generators so that you can perform maintenance on the many types found in AF applications.

7. Noninterlace Sync Generators

7-1. The sync generator is a simple noninterlace (also called a sequential or progressive) system produces a minimum of signal outputs. We will identify these signals and explain how they may be produced. A more elaborate system will then be studied. The basic sections, pertinent waveforms, and possible adjustments are considered for both types of sync generators covered in this section.

7-2. **Simplest Type.** The essential outputs for any TV system are sync and blanking signals. As you know, two sync signals are necessary, one to control horizontal scanning and the other to control vertical scanning. Two blanking signals are also required to prevent the horizontal and vertical retraces from appearing during the flyback times. The simple sync generator illustrated in figure 29 contains a blanking mixer that produces a composite blanking waveform. This mixer, in addition to the horizontal and vertical oscillator, constitute the three basic sections of this sync generator.

7-3. In a noninterlace system there is no need for any tie-in between the horizontal and vertical oscillators. A variation in frequency of one or the other changes the frames per second or lines per frame. For many practical purposes this is of no consequence and is not noticeable. The vertical oscillator can be a blocking oscillator (tube or transistor type) that is locked-in with the 60-cycle line. A vertical sweep signal can be obtained from this oscillator since a sawtooth waveform appears across the blocking capacitor during the cutoff time. This waveform can be amplified and fed to the vertical deflection coils, as indicated in figure 29. Recall that a blocking oscillator generates sharp pulses when the tube (or transistor) conducts. Note in the block diagram that these pulses are fed to the vertical sync buffer and the blanking mixer. The buffer, of course, minimizes loading effects on the oscillator and also provides amplification.

7-4. Either by means of a waveshaping network or by special circuit design, the horizontal oscillator generates the signal for horizontal scanning. In addition, like the vertical oscillator, it produces sync pulses which are applied to a buffer amplifier. Its frequency is usually in the vicinity of 20 kc. Observe in figure 29 that this oscillator's output is also fed to the high voltage rectifier that is readily excited via a step-up transformer. This amounts to having a flyback HV system, the operation of which was discussed in the previous chapter.

7-5. Adjustments that affect vertical linearity and height are generally made in the vertical oscillator section. Tuning provisions are ordinarily not provided since the frequency is 60 cps and locked to the line. The horizontal oscillator section has adjustments that make it possible to change the amplitude of the outputs; tuning may or may not be variable, depending upon the particular system. If this very simple type of sync generator is adjusted to produce a 15.75-kc horizontal frequency, its output pulses can be used for locking a standard broadcast TV receiver.

7-6. **Multiple-Pulse Type.** Figure 30 shows a sync generator that produces several pulse waveforms: mixed sync, mixed blanking, vertical drive, and horizontal drive signals. Such a variety of outputs may be required for a more elaborate noninterlace system. The mixed sync can be inserted with the camera's output to obtain a composite video signal for single-cable transmission or for modulation. The mixed blanking signal is fed to the camera as are the separate vertical and horizontal drive pulses. Unlike the simple sync generator previously discussed, this sync generator produces sync and blanking pulses that differ in pulse width. The vertical and horizontal blanking pulses are usually greater than twice the width of their corresponding sync pulses. Waveshaping and pulse-forming circuits are therefore necessary to bring about this difference.

7-7. *Functional analysis.* The 60-cps line signal is shown in figure 30 to be the input to a waveshaping network, called a squarer and peaker, which is nothing more than an overdriven amplifier and differentiating circuit. Because the 60-cps input signal causes positive and negative clipping, a square-wave output is obtained from the amplifier. This output is applied to a short-time constant RC series circuit so that positive- and negative-going spikes appear across the resistor. The positive-going spikes precisely synchronize the vertical oscillator frequency with the 60-cps line frequency. The shaping of the vertical oscillator output pulses to a prescribed height and width is done by the vertical amplifier-clipper. The amplifier-clipper output pulses are applied to a blanking shaper and also to a drive shaper. In addition to squaring-up the vertical pulse, the drive shaper narrows it to about half the width of the vertical blanking pulse. These narrowed pulses are fed into the sync mixer and out to the camera(s) for triggering the vertical sweep.

7-8. The horizontal oscillator is a free-running type designed to operate with some blocking action. Pulses from it are shaped for horizontal blanking and drive. Like the vertical drive shaper, the horizontal drive shaper decreases the pulse width so that it is about half that of the horizontal blanking pulse. The output of the horizontal drive shaper is used to trigger the camera's horizontal sweep; this output is also sent to the sync mixer.

7-9. Both the blanking mixer and sync mixer are designed so that the horizontal pulses do not appear in the output during the vertical pulse time. Figure 31,A, illustrates how this is easily accomplished by clipping the horizontal pulses

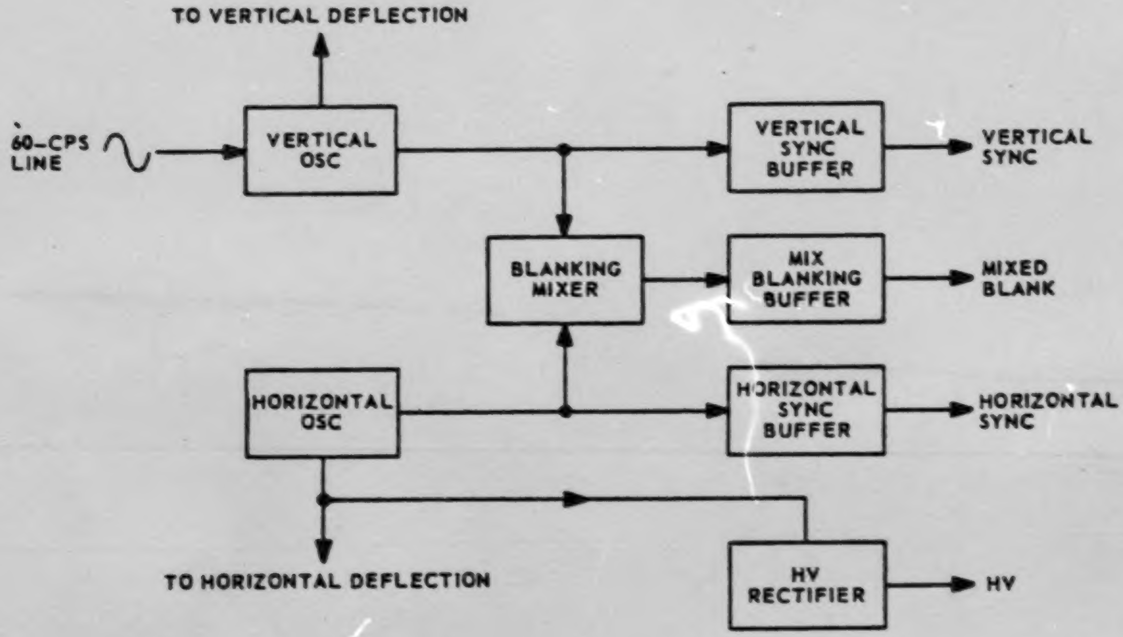


Figure 29. Simple noninterlace sync generator.

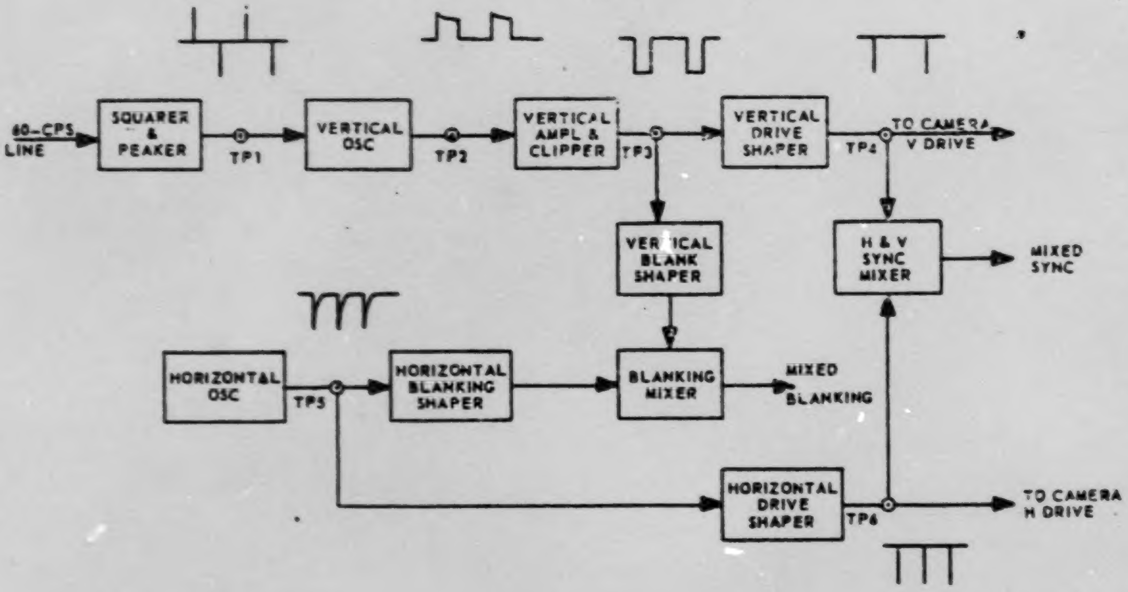


Figure 30. Multipulse noninterlace sync generator.

that ride the vertical pulse. Figure 31,B, further illustrates that because of the difference in pulse widths, horizontal sync (same for drive) is resumed before the vertical blank pulse terminates. Therefore, the horizontal oscillator will be locked-in before picture information appears on the screen. For example, if the vertical sync pulse is half that of a 1620-μsec blanking pulse, we can determine the number of 15.75-kc horizontal syncs (63.5-μsec pulse period) that will be present during vertical blanking by dividing 810 μsec by 63.5 μsec. This gives us 12 horizontal sync pulses before picture information appears on the screen.

7-10. *Adjustments and troubles.* Adjustments and alignment of the pulses are made in the pulse-forming circuits of the clipper or shapers. Since the vertical oscillator does not generate the sweep waveform, as was the case for the simple sync generator described, linearity and height adjustments are not needed. Provision is made, however, to adjust the output pulse width of the vertical oscillator if this is critical. Ordinarily, the vertical oscillator will not be tunable. But a transformer feedback-type horizontal oscillator will likely be slug tuned; for versatility, this oscillator may be so designed that it can be tuned to operate at the 15.75-kc standard scan rate.

7-11. Let us give some thought to troubles that can be indicated by waveform presentations. Suppose, for example, that the vertical pulse of the mixed sync output is abnormally wide; a check of the mixed blanking output is normal, as illustrated in figure 31,B. It is logical to suspect that the trouble is in the pulse-shaping circuit of the vertical drive shaper. This can be confirmed by testing the signals at TP4 and TP3, figure 30. A different trouble would be indicated if the vertical blanking pulse was also too wide. The signals illustrated at TP1 and TP2 should point up the trouble. Depending upon the shapes of the waveforms at these test points, you can isolate the trouble to a section: squarer and peaker, vertical oscillator, or vertical amplifier/clipper. Similarly, troubles that evidence themselves as waveform abnormalities can be tracked down and identified with a particular section.

8. Interlace Sync Generators

8-1. When many of us think of interlace scanning, a complicated composite signal comes to mind. This is natural since the Electronic Industries Association (EIA, formerly RETMA) composite signal standards are widely used. In the latter portion of this section we will analyze the sync generator required to produce standard output waveforms. But before becoming involved with such a complex sync generator, it is well for you to realize that interlace scanning can be accomplished with a relatively simple sync generator. A simple type may be quite satisfactory for certain closed circuit applications; this being the case, a more costly, elaborate type would not be warranted. Since you may

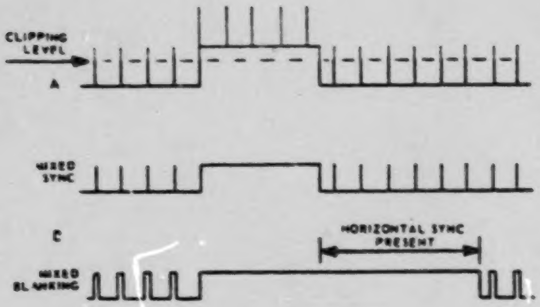


Figure 31. Noninterlace multiple-pulse waveforms.

have to maintain a simple interlace sync generator, you should know what it consists of and understand how it functions. Furthermore, by studying its basic sections and the requirements peculiar to any interlace system, you can further your understanding of the more complex sophisticated types.

8-2. **Requirements for Interlace.** Unlike the noninterlace system, an interlace system must have a rigid control established between the horizontal and vertical scanning. Such control can be achieved in either of two ways: (1) each oscillator, vertical and horizontal, can be precisely timed, or (2) a fixed timing relationship between the horizontal and vertical scans can be maintained. Since the first way demands extreme stability, the second way is more practical. By using a master oscillator and counters (frequency dividers), a fixed timing relationship is maintained such that the ratio of scanning frequencies is constant. You know that the standard ratio in this country is 262 + ½, which is the quotient obtained when 15.750 pps is divided by 60 pps. It is absolutely essential that this quotient be an integral number *plus a half*. This insures that the vertical scan will alternately terminate on a half line and whole line, thereby positioning successive sets of lines (fields) between each other.

8-3. *Basic sections.* In figure 32 are the four basic sections of an interlace sync generator. Admittedly, four sections are inadequate to provide the degree of reliability needed for practical applications. Nonetheless, let us discuss these sections because they are essential to all our standard-frequency interlace sync generators.

8-4. Since the master oscillator (mo) generates the timing pulses that govern the entire system, it must be highly stable. There are various types that can be designed to meet this requirement. In your previous training you have studied multivibrators and blocking oscillators that are commonly used; therefore, you should have little difficulty recognizing and understanding the operation of modified versions that may be used. The mo generally has an adjustment to alter its frequency. Other adjustments may also be provided to vary its pulse width and to set the midpoint of its range. In a standard system, it will generate pulses at twice the horizontal scan frequency (31.5 kc). These pulses are divided by the 2:1 counter to provide timing the horizontal sync and blank to the standard line scan rate (15.75 kc). The vertical scan rate is established by the 525:1 counter section which divides the mo pulses to produce 60 pps for timing the vertical sync and blank.

8-5. In case you do not fully appreciate the fixed ratio relationship that is maintained by this scheme of counters, let us note the results when the mo frequency shifts. Suppose the mo output increases to 32,550 pps. Dividing by two we find the horizontal scan rate is 16,275 cps. Dividing by 525, the vertical scan rate is 62 cps. This tells us that there are more lines per second and more fields per second than normal, but our primary interest is in the number of lines per field. This ratio is determined by dividing 16,275 cps by 62 cps. Doing so, we learn that there are still 262½ lines per field. Whatever mo frequency change you may assume will give the same ratio; therefore, you must conclude that this ratio 262½ is fixed for the system if the counters divide properly.

8-6. *Counters.* Three commonly used circuits

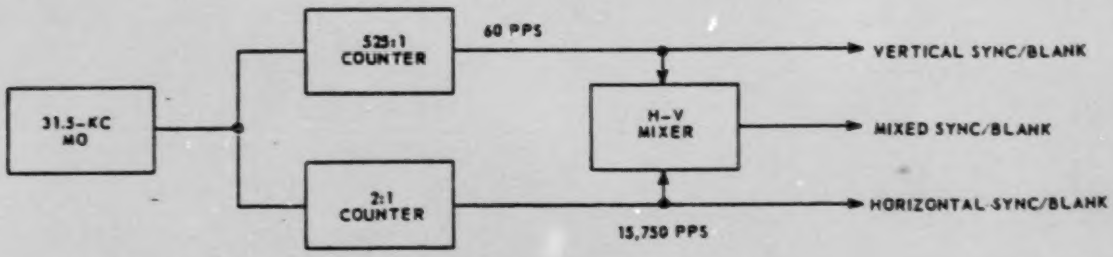
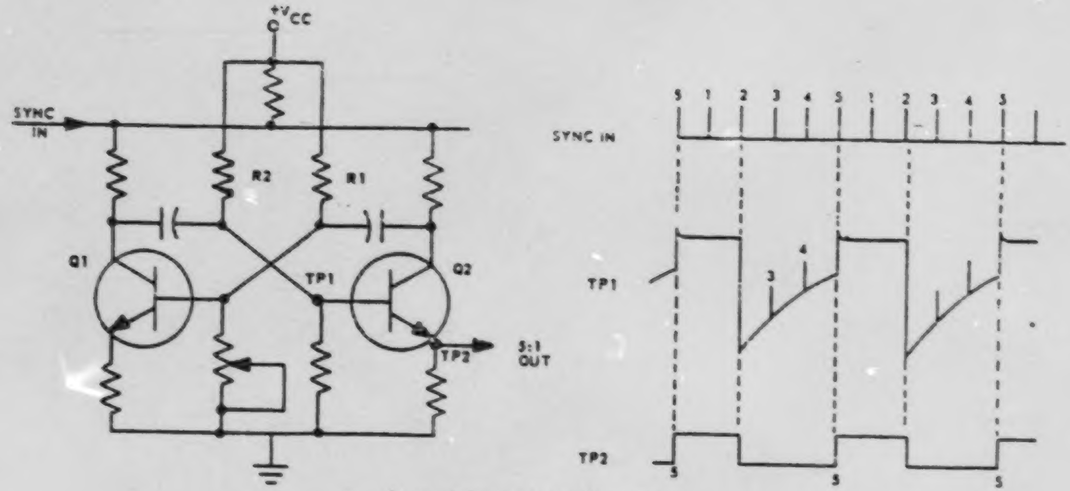
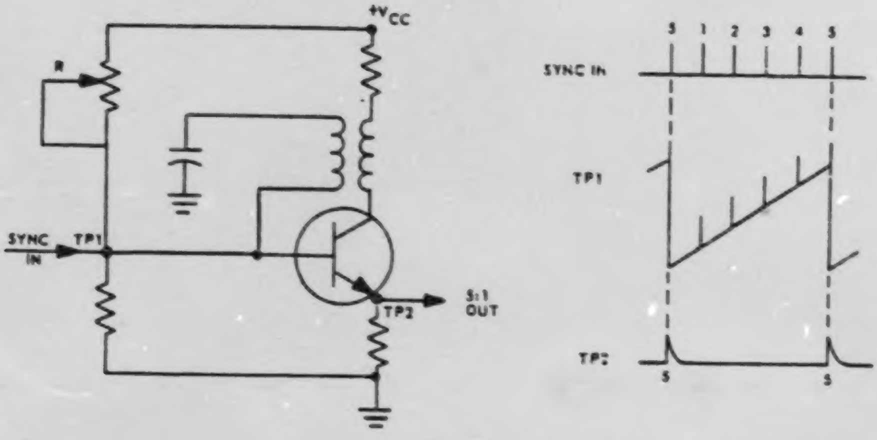


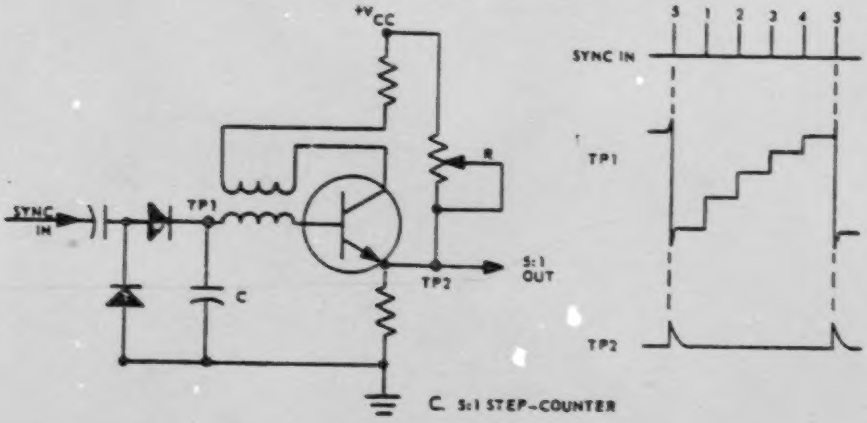
Figure 32. Basic sections of interlace sync generator.


+VCC
SYNC IN
R2
R1
Q1
Q2
TP1
TP2
5:1 OUT
5 1 2 3 4 5 1 2 3 4 5
SYNC IN
TP1
3
4
TP2
5
5
5

A. MULTIVIBRATOR 5:1 COUNTER


+VCC
R
SYNC IN
TP1
TP2
5:1 OUT
5 1 2 3 4 5
SYNC IN
TP1
TP2
5
5

B. BLOCKING OSCILLATOR 5:1 COUNTER


+VCC
R
SYNC IN
TP1
TP2
C
5:1 OUT
5 1 2 3 4 5
SYNC IN
TP1
TP2

C. 5:1 STEP-COUNTER

Figure 33. Common types of counters.

for dividing pulse frequencies in sync generators are the multivibrator counter, the blocking-oscillator counter, and the step-counter. These circuits are shown for your review in figure 33. Recognize the similarity of the transistor configuration with the tube circuits which are perhaps more familiar to you. The operating principles are identical whether tube or transistor. Since you should know how these circuits function, we will not analyze them in this course. However, we will point out a few significant facts for you to remember. In figure 33,A, note that the time constant of the base circuit Q_1 is shorter than that of Q_2. This is evident from the waveforms at TP1 and TP2 which show Q_2 conducting (Q_1 cut off) for two pulse periods and cut off (Q_1 conducting) for three pulse periods. The resistors R_1 and R_2 are necessary to properly bias the transistors. These resistors would not be needed in a similar tube multivibrator. Figure 33,B, shows the transistor version to be very much like a conventional tube blocking oscillator counter. Bias, of course, is different; it can be adjusted with R. The step-counter, figure 33,C, corresponds to the tube step-counter you have studied. Recall that the step-charging circuit works into a blocked oscillator. By means of R, bias can be adjusted to unblock the oscillator and discharge C at the prescribed level. Unlike the other two types of counters, this circuit is not free-running. Incoming pulses directly control the count; therefore, it is less susceptible to miscount caused by trigger frequency variations. It is more precise, but it is limited to a maximum count of about 10, because the steps do not increase in equal increments (see fig. 33,C). Stability of the count becomes more subject to circuit variations as the voltage step decreases at the higher levels.

8-7. The stability of the trigger's amplitude is important for all three counters mentioned. Furthermore, the higher the count, the more stringent becomes the stability requirement. Although special circuits have been designed for high counts, a simple resonant circuit can improve stability to a marked degree. Figure 34 shows how such a circuit modifies the normal grid waveform of the blocking oscillator counter. The resonant stabilizer is tuned to approximately 1.5 the free-running oscillator frequency so as to produce a trough just prior to the desired fifteenth trigger pulse. Consequently, the preceding pulses that are likely to trigger the oscillator prematurely appear well below the conduction level.

8-8. Not as commonplace as other circuits, the phantastron circuit can be designed for reliable counting. Ordinarily, this circuit is employed for pulse delay, but let us consider how its operation lends itself to counting. Figure 35 shows the phantastron counter circuit and waveforms which we will refer to in our explanation. Specific potentials have been chosen to give you an idea of the magnitude of voltages involved. These values should be regarded as approximate and, of course, will depend on the particular tube employed.

8-9. To begin, note that there is one output pulse (waveform e_o) for every five input pulses (waveform e_1). Every fifth input pulse triggers the phantastron to cause a complete cycle of its operation. This circuit is not free-running; it must be activated by a negative-going pulse. In

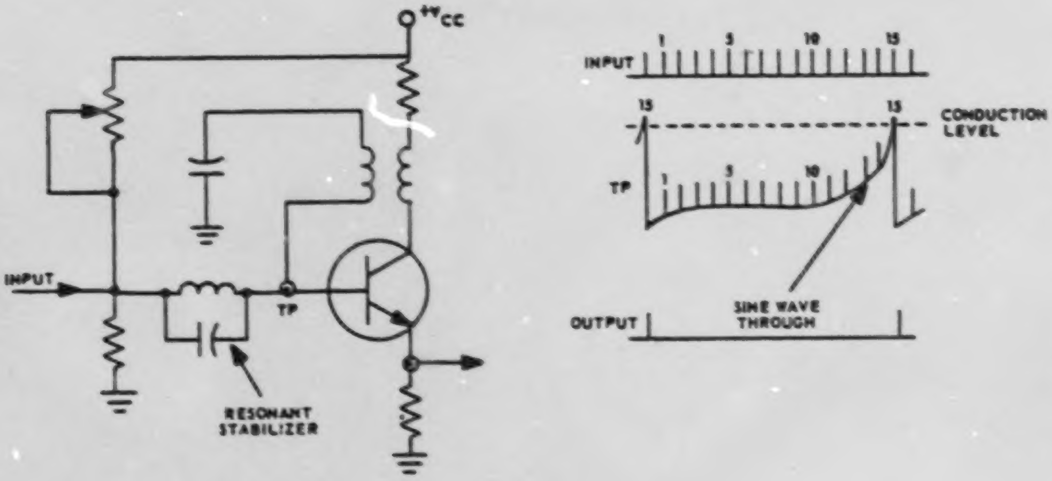


Figure 34. Stabilized blocking oscillator.

its pretriggered condition there is no plate current; thus the plate is at B+ potential. However, cathode current flows since grid 2 draws current. Because grid 3 is biased at a less positive potential (e_{g3}) than the cathode, this grid does not draw current and prevents current flow to the plate. Study the waveform values immediately prior to t_5. These potentials will persist until the circuit is triggered.

8-10. You can best understand the action of the phantastron when it is triggered by dividing it into three successive phases. The first phase is an extremely rapid change which occurs when the negative trigger, coupled through C1 to the control grid, causes e_k to decrease. This decreases the bias between grid 3 and the cathode, thereby permitting plate current to flow. Consequently, plate voltage e_p drops to give regenerative feedback and drives the control grid instantaneously to a negative value (−5v). You can see the effects of this action by studying the t_5 waveforms in figure 35. The second phase is a slow linear change. After the trigger, C_1 gradually goes positive because of counteraction of the decreasing plate voltage e_p. The time constant of this change is effectively extended by the amplifying action of the tube. It is worthwhile to point out that during this second phase the input pulses at times t_1, t_2, t_3, and t_4 are ineffective. In fact, they are blocked by the action of the disconnect diode D_1. From the waveforms illustrated, you can see the changes that take place during this phase. The third phase is initiated when e_K rises to such a value that the bias between the cathode and grid 3 cuts off plate current. When this happens the circuit reverts back to its pretriggered condition. The next trigger, t_5, causes the cycle to recur.

8-11. Observe that the output is taken off the cathode and applied across C_2 and R_2 in series. The time constant R_2C_2 is short for the waveform e_K so that positive-and negative-going spikes appear across R_2. The diode D_2 passes only the negative spikes as illustrated in figure 35.

8-12. The phantastron is quite stable under power supply variations. Changes of supply voltage vary the d-c potentials proportionally on the tube elements and are therefore minimized; overall circuit performance is virtually unaffected. Because the pulse width can be varied by a d-c voltage, the circuit can be remotely controlled through unshielded cables. Note also in figure 35 that control-grid bias is variable. A change in this bias alters the pulse width so that the phantastron can be adjusted for its designed count. Although we chose to illustrate a five

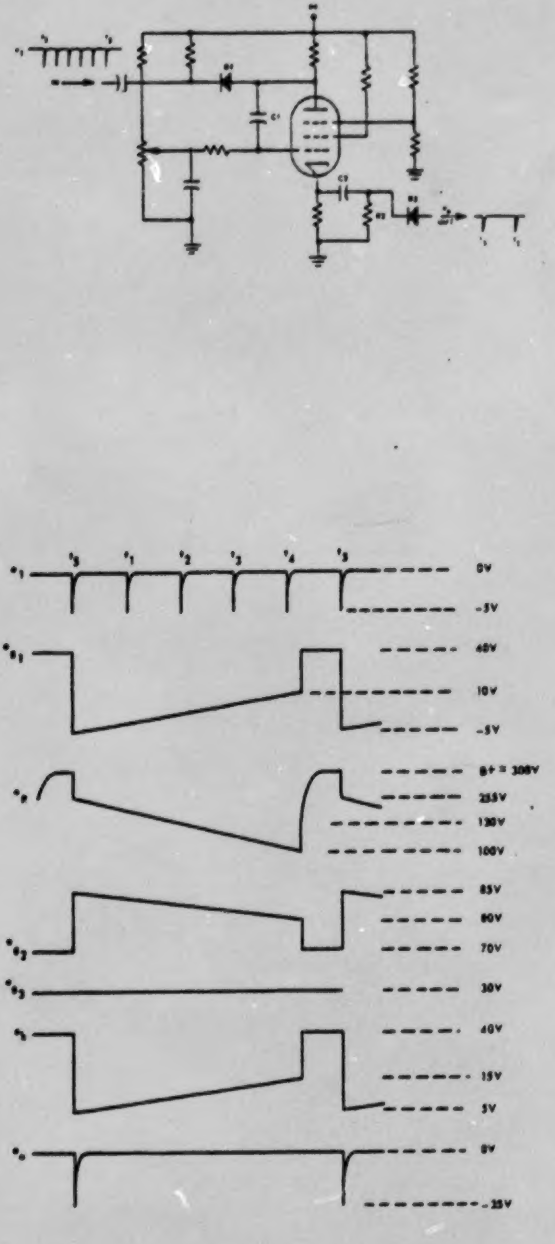


Figure 35. Phantastron counter and associated waveforms.

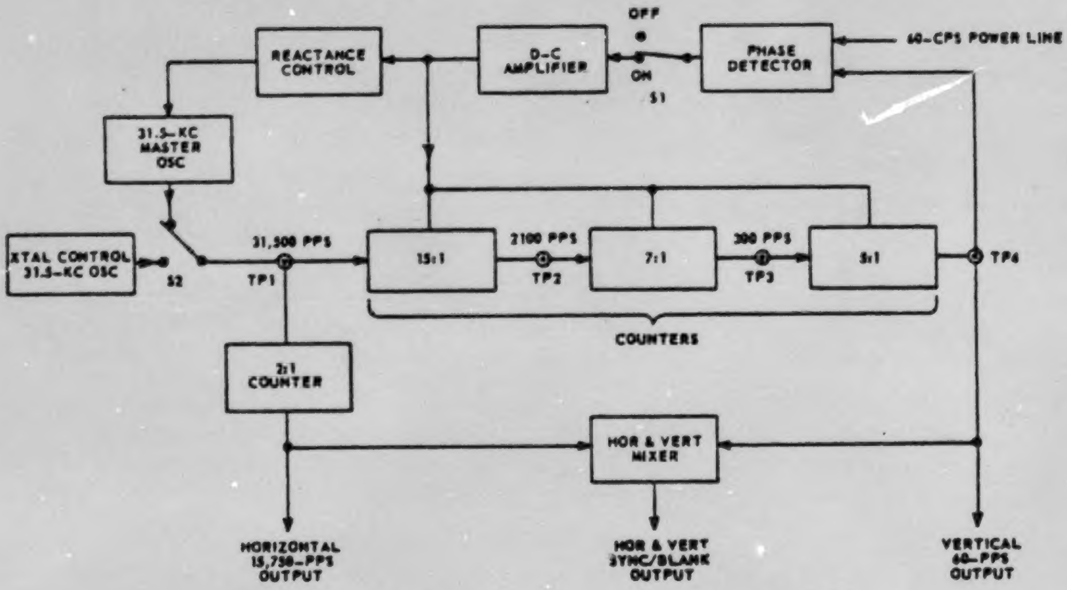

OFF
ON
S1
REACTANCE CONTROL
D-C AMPLIFIER
PHASE DETECTOR
60-CPS POWER LINE
31.5-KC MASTER OSC
XTAL CONTROL 31.5-KC OSC
S2
31,500 PPS
TP1
15:1
2100 PPS
TP2
7:1
300 PPS
TP3
5:1
TP4
COUNTERS
2:1 COUNTER
HOR & VERT MIXER
HORIZONTAL 15,750-PPS OUTPUT
HOR & VERT SYNC/BLANK OUTPUT
VERTICAL 60-PPS OUTPUT

Figure 36. Random interlace sync generator.

count, much higher counts can be readily obtained.

8-13. **Random Interlace Type.** In addition to the basic sections, a practical interlace sync generator will contain an afc network and a crystal control oscillator. Figure 36 shows their inclusion and arrangement. However, since we have discussed counters, let us first consider how pulses of a desired width and shape can be obtained as outputs from the counters. By studying the output waveforms, you will see why this sync generator is called a random interlace type. Then we will discuss afc and the use of the crystal control oscillator for calibration.

8-14. *Outputs.* With the switch S2 in the position shown (fig. 36), the 31.5-kc signal is supplied by the mo to the 2:1 counter to develop horizontal output pulses and to the 15:1 and subsequent counters to develop vertical output pulses. We see that both horizontal and vertical pulses are fed into a mixer, the output of which is a composite signal. The three outputs from this sync generator are the minimum required. The horizontal and vertical outputs synchronize and drive the scanning circuits to produce the proper raster. The output pulses of the mixer are sent to the camera for blanking and become the sync/blank pulses in the camera's composite video output signal. Indeed this is a simple system, but it is important to recognize that the requirements for interlace are met. This is brought to your attention in figure 37, which shows the time

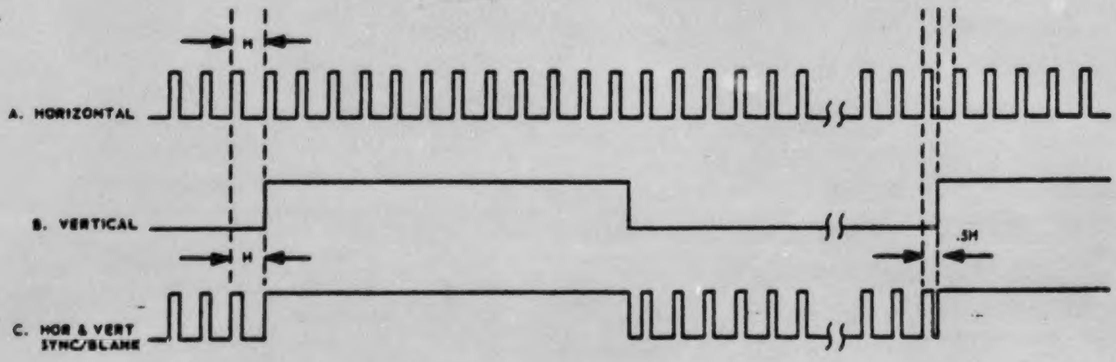

H
A. HORIZONTAL
B. VERTICAL
H
.5H
C. HOR & VERT SYNC/BLANK

Figure 37. Output waveforms random interlace sync generator.

relationships of horizontal and vertical pulses per second (pps). Note that a full horizontal period (H) precedes the vertical pulse (left side), whereas a half period (0.5H) precedes the next vertical pulse. Thus, there is the half-line time difference between successive fields which is needed for interlace.

8-15. Since the outputs illustrated are idealized, you may well ask how they are shaped. Clipper and shaper circuits were mentioned earlier, but none are identified in the block diagram of figure 36. This is because counters can be designed to produce properly shaped pulses. Remember that a rectangular pulse is obtained from a multivibrator counter. The pulse width of this counter is easily altered by adjusting the relative time constants of the feedback circuits. Moreover, by regulating these time constants, frequency can be kept at a specified value. If another type of counter is employed, the pulse may be too narrow. A small shunting capacitor, connected across the counter's output, will effectively widen the pulse. A clipping diode can be incorporated to square the pulse at a prescribed level.

8-16. Referring to figure 37,C, you find that no horizontal pulses are present during the time of the vertical pulse. For the length of the vertical pulse, there is no sync signal for the monitor's horizontal oscillator. Such being the case, the frequency of this oscillator can shift and, as a result, the scan may not interlace. In other words, interlace is not insured since horizontal sync is not continuous. Because the relationship of alternate fields is a matter of probability, this scanning is appropriately called random interlace. As you would expect, random interlace is noticeable, but for some applications it is satisfactory. On a small screen kinescope, picture quality is adequate for good viewing.

8-17. *Afc and calibration.* The purpose of afc in an interlace sync generator is to lock-in the 60-cycle field rate with the 60-cycle power line. Unless this is done, a 60- or 120-cycle hum pickup will create raster distortion and/or shading changes that move vertically across the screen. The afc does not eliminate the pattern of disturbance(s) caused by such pickup, but it does make the pattern stationary. A stationary pattern is far less annoying to the viewer than a continuously moving one. In fact, with 60-cycle lock-in a small amount of hum pickup will go unnoticed. Afc is therefore a feature found in virtually all interlace sync generators, not just random types.

8-18. The afc network illustrated in figure 36 consists of a phase detector (discriminator), a d-c amplifier, and a reactance control circuit. The phase detector may be one of several types you should know. Whichever type is used, it will have two inputs: the vertical 60-pps sync generator output and the 60-cps line signal. The phase detector develops a d-c error voltage whenever there is a phase difference between these two inputs. Note in the block diagram that the output of the phase detector (error voltage) is amplified by a d-c amplifier before it is applied for control purposes. This amplification is usually needed. Depending upon the type counters, the error voltage may not be coupled to the counter chain as shown in our diagram. We can be certain, however, that the error voltage will be sent to a reactance control circuit which acts to change the mo frequency. The reactance control section can employ a reactance tube amplifier or a solid state device such as a varicap (other names are semicap, varactor diode, etc.). A varicap is a specially designed crystal diode that has a greater than ordinary variation of capacitance with changes in reverse bias. By applying the error voltage to a reverse-biased varicap, capacitance change can be used to control the frequency of the 31.5-kc mo. If properly designed, the mo will automatically adjust to minimize any frequency difference between the inputs to the phase detector. This means that the vertical output signal is locked-in to the 60-cycle line.

8-19. Although afc functions to hold the sync outputs to their proper frequencies, it is necessary that the mo and counters be within a prescribed range for lock-in. Moreover, interlace depends upon the sync generator's frequency relationships. To insure proper operation, it is therefore necessary to calibrate the mo and counters.

8-20. You should first calibrate the mo so that its free-running frequency is 31.5 kc. Switch S1 (see fig. 36) must be put in the OFF position. This removes any error voltage which affects the mo. Using an oscilloscope, tune the mo until its frequency is exactly that of the 31.5-kc crystal oscillator. There will probably be amplitude checks and adjustments specified for any particular mo. When you are sure that the mo has the prescribed output, the counters can then be calibrated.

8-21. Counters are checked successively starting with the one nearest the mo. Thus, in the vertical counter chain the 15:1 counter is calibrated first. Leave S1 in the OFF position. You should follow the calibrating procedures and use the test equipment prescribed by the manufacturer. After calibrating all counters, switch S1 to the ON position, and the generator should lock in rigidly with the 60-cycle power-line frequency. However, in the event that the powerline frequency is not 60 cps, leave S1 in the OFF position. Either the mo or crystal oscillator can be selected with switch S2. The mo offers no advantage when the afc is disabled.

8-22. **Standard Interlace Type.** There are nonstandard systems, designed for special purposes, that can reliably interlace using a very simple sync waveform. Such systems, however, have marginal performance capabilities for general applications and have insufficient reliability for broadcasting. Consequently, most American TV systems use EIA (RETMA) sync waveform standards. Although these systems must employ a relatively complex sync generator, a standardized system offers many advantages over systems that have less rigorous requirements. Before undertaking an analysis of the sync generator needed, we will review the EIA signal waveforms. A thorough knowledge of the details of this waveform is essential to an understanding of the workability of the system as a whole.

8-23. *Signal standards.* Although you are familiar with the EIA standard waveforms illustrated in figure 38, it is well to call to mind the functions of the various pulses involved. In addition to the sync and blanking pulses that have been discussed previously, this signal contains equalizing pulses. Moreover, it has a serrated vertical sync pulse. These equalizing pulses and serrations are distinctive features that provide continuous horizontal sync and insure proper interlace.

8-24. A group of six narrow equalizing pulses immediately precedes the vertical sync pulse, and a similar group of six follows it. These pulses occur at twice the line frequency (31.5 kc). This doubling of frequency is necessary if alternate fields are to be properly synchronized for interlacing. Note that the first, third, and fifth equalizing pulses are used as horizontal sync for the fields that end in a complete line (period H); whereas, the second, fourth, and sixth equalizing pulses are used for the fields that end in a half line (0.5H). Besides maintaining horizontal sync, the equalizing pulses serve to time precisely the vertical sync pulses.

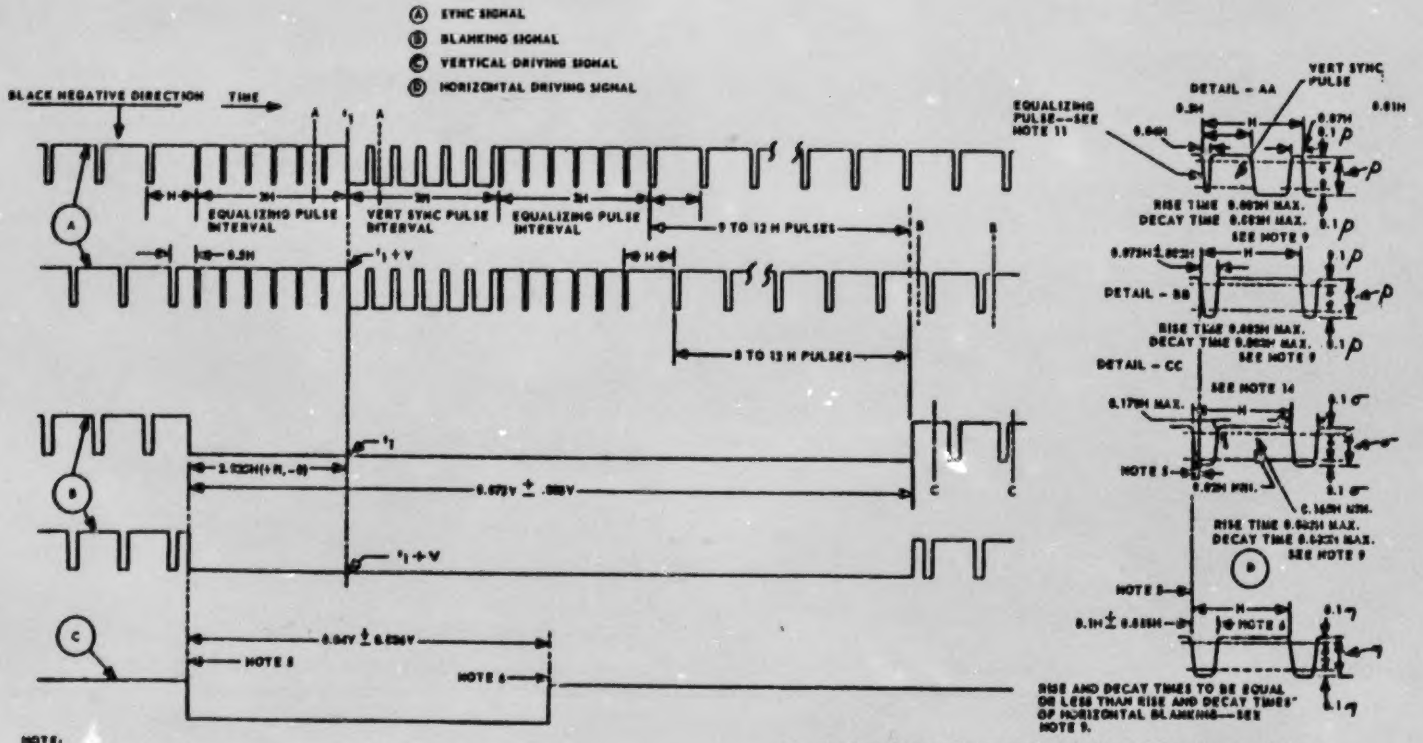
8-25. If vertical sync is not precise, interlace is jeopardized. A slight discrepancy in the vertical scan will cause the lines of alternate fields to come together. This effect, called pairing, reduces vertical resolution and the line structure becomes visible at normal viewing distance. Because the time between the last horizontal pulse and the vertical sync differs by 0.5H for alternate fields, the residual charge from the integrating circuit (in the receiver or monitor) differs also. Figure 39,A, shows how this residual charge will introduce a discrepancy in the vertical sync. Figure 39,B, shows how the equalizing pulses prevent this inherent discrepancy which would cause "pairing." This should remind you how vital equalizing pulses are to the system.

8-26. Unless the vertical sync pulse is serrated as shown, horizontal sync will be disrupted. Examine this serrated pulse and observe that the trailing edge of the serration is used for horizontal synchronization. A differentiating circuit in the receiver or monitor develops pulses of the correct polarity when the trailing edge of the serration occurs. Like equalizing pulses, the serrations must have twice the horizontal scan frequency to accomodate alternate fields.

8-27. The times and tolerances for the various pulses are specified in figure 38. A table of values is given in figure 40 for your convenience. Both of these figures contain much information that is pertinent to the maintenance of a standard sync generator. Checks of pulse widths and adjustments will necessitate reference to these standards. It will benefit you, therefore, to read the explanatory notes and relate the waveforms and values. The close tolerances indicate the stability required of the sync generator. The variety of waveforms points up the fact that the sync generator must be a relatively complex piece of equipment.

8-28. *Functional analysis.* The block diagram in figure 41,A, shows the essential sections that function to produce the standard sync waveforms. Bear in mind that these sections may be made up of several stages and associated circuitry. Furthermore, remember that the circuits within these sections are basic ones or modified versions of circuits covered in your fundamentals training. Our purpose is to analyze the functional relationships of the various sections. Once you grasp how the standard waveforms can be synthesized, you will better understand the operation of this type sync generator.

8-29. Refer to figure 41,A. You should recognize the sections to the far left in the diagram. The mo section contains a crystal-controlled oscillator (not shown) for calibration and is locked in by the afc section. To obtain the vertical 60 pps, a 525:1 counter chain is used. Generally this chain consists of counters that divide the frequency in steps of 7:1, 5:1, 5:1, and 3:1. The 60-pps signal is used for afc and is also fed to the vertical sections indicated. Except for the vertical drive output which is sent to the camera, the outputs from these sections are coupled into other sections for further processing. A signal from the 31.5-kc mo is divided by 2:1 counter to obtain the standard horizontal line rate of 15.75 kc. We see that this signal is applied to a delay section from which four outputs


Ⓐ SYNC SIGNAL
Ⓑ BLANKING SIGNAL
Ⓒ VERTICAL DRIVING SIGNAL
Ⓓ HORIZONTAL DRIVING SIGNAL
BLACK NEGATIVE DIRECTION
TIME
A
t1
A
H
3H
EQUALIZING PULSE INTERVAL
VERT SYNC PULSE INTERVAL
EQUALIZING PULSE INTERVAL
9 TO 12 H PULSES
B
0.5H
t1 + V
8 TO 12 H PULSES
t1
0.075V ± .005V
C
t1 + V
0.04V ± 0.006V
NOTE 5
NOTE 6
DETAIL - AA
VERT SYNC PULSE
EQUALIZING PULSE--SEE NOTE 11
0.5H
0.07H
0.01H
0.04H
0.1 P
P
RISE TIME 0.003H MAX.
DECAY TIME 0.003H MAX.
SEE NOTE 9
0.075H ± 0.005H
DETAIL - BB
RISE TIME 0.003H MAX.
DECAY TIME 0.003H MAX.
SEE NOTE 9
DETAIL - CC
SEE NOTE 14
0.175H MAX.
0.1 σ
σ
NOTE 5
0.02H MIN.
0.165H MIN.
RISE TIME 0.003H MAX.
DECAY TIME 0.003H MAX.
SEE NOTE 9
D
NOTE 5
0.1H ± 0.005H
NOTE 6
0.1 η
η

RISE AND DECAY TIMES TO BE EQUAL OR LESS THAN RISE AND DECAY TIMES OF HORIZONTAL BLANKING—SEE NOTE 9.

NOTE:

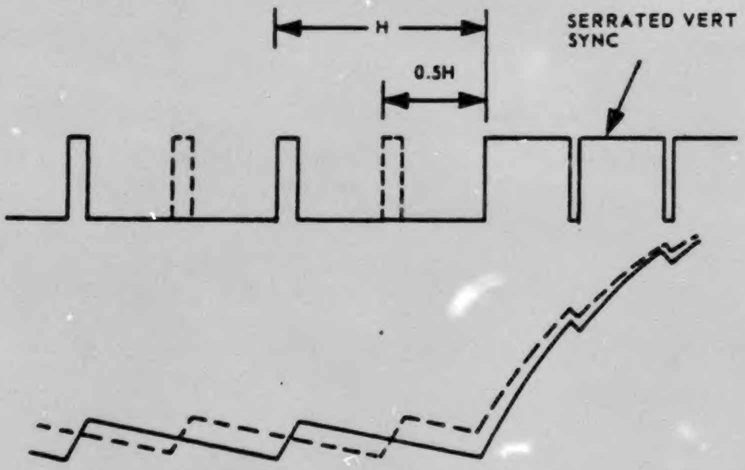
1 - H-TIME FROM START OF ONE LINE TO START OF NEXT LINE.
2 - V-TIME START OF ONE FIELD TO START OF NEXT FIELD.
3 - LEADING AND TRAILING EDGES OF VERTICAL DRIVING AND VERTICAL BLANKING SIGNALS SHOULD BE COMPLETE IN LESS THAN 0.1H.
4 - ALL TOLERANCES AND LIMITS SHOWN IN THIS DRAWING ARE PERMISSIBLE ONLY FOR LONG TIME VARIATIONS.
5 - TIMING ADJUSTMENT, IF ANY, MUST INCLUDE THIS CONDITION.
6 - THE VERTICAL DRIVING PULSE DURATION SHALL BE 0.04V ± 0.006V. THE HORIZONTAL DRIVING PULSE DURATION SHALL BE 0.1H ± 0.005H.
7 - THE TIME RELATIONSHIP AND WAVEFORM OF THE BLANKING AND SYNC SIGNALS SHALL BE SUCH THAT THEIR ADDITION WILL RESULT IN A STANDARD RETMA SIGNAL. THE TIME RELATIONSHIP MUST BE ADJUSTABLE IN ORDER TO SATISFY THIS RELATIONSHIP FOR THE CONDITION WHERE THE BLANKING SIGNAL IS DELAYED WITH RESPECT TO THE SYNC SIGNAL OVER THE RANGE FROM 0.0H TO 0.02H.
8 - THE STANDARD RETMA VALUES OF FREQUENCY AND RATE OF CHANGE OF FREQUENCY FOR THE HORIZONTAL COMPONENTS OF THE SYNC SIGNAL AT THE OUTPUT OF THE PICTURE LINE AMPLIFIER SHALL ALSO APPLY TO THE RECOMMENDED SYNC GENERATOR.
9 - ALL RISE AND DECAY TIMES TO BE MEASURED BETWEEN 0.1 AND 0.9 AMPLITUDE REFERENCE LINES.
10 - THE TIME OF OCCURRENCE OF THE LEADING EDGE OF ANY HORIZONTAL PULSE "N" OF ANY GROUP OF 20 HORIZONTAL PULSES APPEARING ON ANY OF THE OUTPUT SIGNALS FROM A STANDARD SYNC GENERATOR SHALL NOT DIFFER FROM "NH" BY MORE THAN 0.0005H WHERE H IS THE AVERAGE INTERVAL BETWEEN THE LEADING EDGES OF THE PULSES AS DETERMINED BY AN AVERAGING PROCESS CARRIED OUT OVER A PERIOD OF NOT LESS THAN 20 NOR MORE THAN 100 LINES.
11 - EQUALIZING PULSE AREA SHALL BE BETWEEN 0.45 AND 0.5 OF THE AREA OF A HORIZONTAL SYNC PULSE.
12 - THE OVERSHOOT ON ANY OF THE PULSES MUST NOT EXCEED 5%.
13 - THE OUTPUT LEVEL OF THE BLANKING SIGNAL AND THE SYNC SIGNAL MUST NOT VARY MORE THAN 2% UNDER THE FOLLOWING CONDITIONS:

    A. THE AC VOLTAGE SUPPLYING THE SYNC GENERATOR MUST BE IN THE RANGE BETWEEN 110V AND 130V AND MUST NOT VARY MORE THAN 5V DURING TEST.
    B. A PERIOD OF 3 HOURS CONTINUOUS OPERATION SHALL BE CONSIDERED ADEQUATE FOR THIS MEASUREMENT, AFTER SUITABLE WARMUP.
    C. THE ROOM AMBIENT MUST BE IN THE RANGE BETWEEN 20 DEGREES AND 40 DEGREES C. AND MUST NOT CHANGE MORE THAN 10 DEGREES C. DURING THIS TEST.

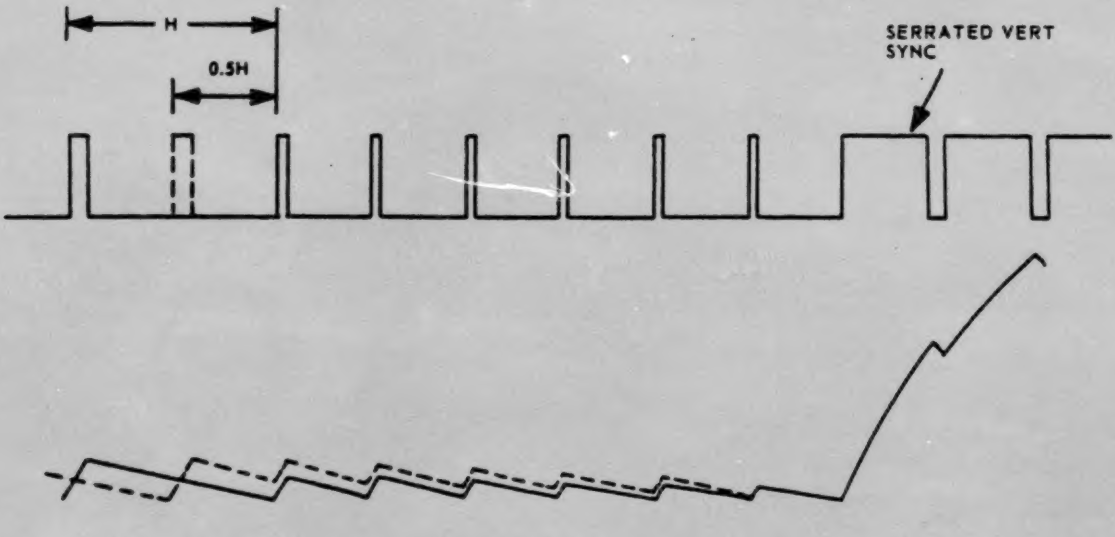
14 - ADJUSTMENT MUST BE POSSIBLE BETWEEN MINIMUM AND MAXIMUM LIMITS SO THAT ASPECT RATIO CAN BE SET TO THE NORMAL VALUE.

Figure 38. EIA (RETMA) standards.

are taken. These outputs are delayed by different amounts to properly time the sections they activate. Delays can be achieved by a multivibrator or phantastron, but a network of passive components (inductors and capacitors) is often used to form a delay line. The delay line consists of many pi sections of series inductance and shunt capacitance. Different delays are tapped off at the junctions as desired up to the maximum obtainable from the line. Outputs of the required time delay can thereby be obtained to control the circuits that form the horizontal sync, notch pulses, horizontal blanking, and horizontal drive. Note in the diagram that the horizontal drive section develops an output from the generator; the outputs from other sections are processed further. Observe also that the 31.5-kc signal is sent to a delay section so that the timing



A. WITHOUT EQUALIZING PULSES



B. WITH EQUALIZING PULSES

Figure 39. Equalizing pulses.

TABLE OF FUNDAMENTAL TV PULSES

PULSE IDENTITY	PULSE RATE (Freq in pps)	DURATION IN H (H = 63.5 microsec)	DURATION IN MICROSECONDS			REPETITION RATE
			Min	Nom	Max	(cps)
H SYNC	15,750	0.075H – 0.089H	4.48	5.08	5.68	15,750
H BLANKING	15,750	0.165H – 0.18H	10.5	11.0	11.43	15,750
EQUALIZING	31,500	0.035H – 0.045H	2.2	2.5	2.8	60
V SYNC	31,500	0.42H – 0.44H	26.9	27.5	28.1	60
V SERRATION	31,500	0.061H – 0.079H	3.85	4.45	5.05	60
V BLANKING	60	13.1H – 21.0H	833.4	1000.0	1333.3	60
H DRIVE	15,750	0.08H – 0.18H	5.25	7.6	11.43	15,750
V DRIVE	60	6.55H – 21.0H	416.5	575.0	1333.3	60

Figure 40. Table of TV pulse standards.

of the equalizing pulse section and vertical pulse section can be controlled.

8-30. The processing or synthesis of waveforms is accomplished by mixing and clipping the output signals of the various sections just mentioned. It is easily seen in figure 41,A. that the composite blanking signal is formed by combining the output pulses of the vertical blank section with those of the horizontal blank section. The blanking signal from the mixer/clip section is shown to be an output from the sync generator. To determine how the sync composite is formed, you will have to study the waveforms illustrated in figure 41,B. These waveforms are identified by letter or number to correspond with the signals indicated in the block diagram. By combining the output 1 from the equalizing pulse section with outputs 2, 3, and 4 from the mixer/clip sections, waveform 5 is produced. The final standard sync signal is obtained by clipping waveform 5 along the dotted lines. This, of course, is done by the sync/clip section.

8-31. Note that signal a is used to eliminate the horizontal pulses of signal b for the time duration 9H; likewise, signal a eliminates the notch pulses for 9H of time. This is evident from waveforms 2 and 3, respectively. Of particular interest is the manner in which waveform 4 is

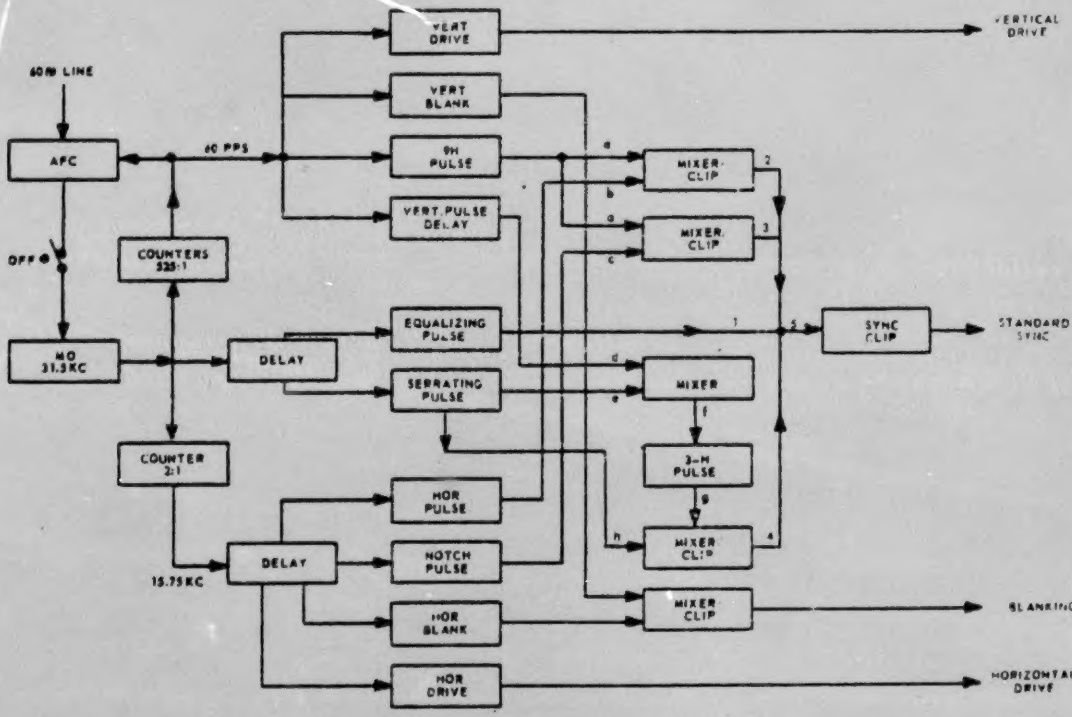

VERT DRIVE
VERTICAL DRIVE
60 ~ LINE
VERT BLANK
AFC
60 PPS
9H PULSE
a
MIXER-CLIP
2
b
a
MIXER CLIP
3
VERT. PULSE DELAY
c
OFF
COUNTERS 525:1
EQUALIZING PULSE
1
5
SYNC CLIP
STANDARD SYNC
MO 31.5KC
DELAY
d
MIXER
SERRATING PULSE
e
f
COUNTER 2:1
3-H PULSE
HOR PULSE
g
h
MIXER CLIP
4
DELAY
NOTCH PULSE
15.75KC
MIXER CLIP
HOR BLANK
BLANKING
HOR DRIVE
HORIZONTAL DRIVE

Figure 41, A. Interlace sync generator, block diagram.

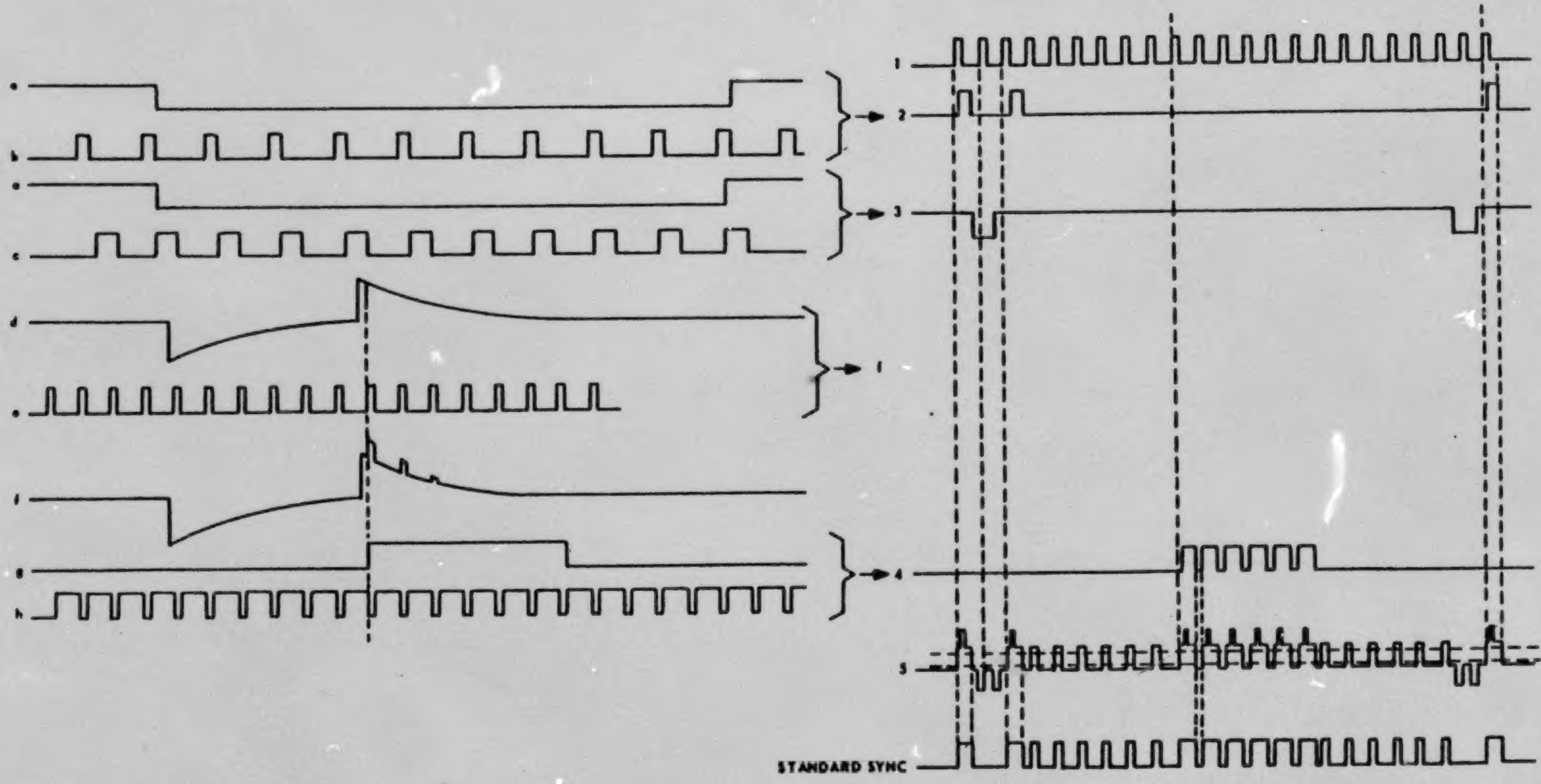

b
c
d
h
1
2
3
4
5
1
STANDARD SYNC

Figure 41, B. Interlace sync generator, waveforms.

developed. Signal d from the vertical delay section is mixed with signal e so the 3H pulse will be triggered by the leading edge of a serrating pulse. Since signal h is e inverted. the trailing edge of the first serration will always occur 0.5H time after the start of the 3H vertical sync pulse. This insures the correct time placement of the serrations to maintain continuous horizontal sync during the vertical sync interval.

8-32. Examine closely the time relationships of the various pulses shown. Be sure you see the need for notch pulses. Determine what pulses establish the width of the horizontal sync.

8-33. *Trouble diagnosis.* If you know the standard signals and how they are formed, you can often diagnose troubles by waveform analysis. Let us cite a particular case in support of this fact.

8-34. Viewing the sync output signal on an oscilloscope, you can see pulses regularly appearing midway between the horizontal sync pulses. Upon closer observation, the unwanted pulses are found to have the same width as the equalizing pulses. This indicates that signal 3 in figure 41.B. is not being supplied to remove the equalizing pulse between horizontal sync pulses The trouble therefore is in the notch pulse section To confirm this diagnosis, you should check the output from the notch pulse section.

8-35. Adjustments are critical in a sync generator of this type. Since much of the timing is dependent upon multivibrator action, a variation in capacitance can set the outputs off in frequency and/or pulse width. Such trouble can be detected by checking waveforms; and adjustment may be all that is needed. Adjustment instructions will be given by the manufacturer of a particular piece of equipment along with illustrated signals at test points. With this information, coupled with an understanding of the principles that have been discussed, many sync generator troubles can be readily diagnosed.

CHAPTER 4

The Camera Chain

AS ALREADY STATED in Chapter 1, all TV systems contain three basic elements—a pickup device, control equipment, and reproduction or display equipment. We have discussed and studied representative types of power supplies and sync generators which are a part of any system. These items are necessary for the proper operation of the camera chain; however, it is important that we know that a camera may have a self-contained power supply, sync generator, and other components. As we make a departure from the simple system, we find additional components such as the switcher and distribution amplifiers. In this chapter we will discuss the construction, function, care, troubleshooting, and repair of the camera chain elements.

9. Cameras

9-1. A camera is an instrument that records a scene in one form or another. The simple box camera changes a scene to a recorded image on a piece of film. The TV camera converts a scene to an electrical signal. The basic items that make up a TV camera are a pickup device, a control and timing system, an output circuit, and of course a source of power. The exact arrangement of these items will vary with a particular arrangement for a specific need. The wide use of TV in broadcast, industry, and education has led to a great variety of camera models, and more are being added each day. In this section we will classify cameras as to the type of pickup tube used. There are a number of pickup tubes in use today and new ones are being experimented with; however, we will limit our discussion to the vidicon and image orthicon types.

9-2. **Vidicon Cameras.** The vidicon camera is a very popular choice of military and industry because it can be constructed in a small package and still deliver a good signal. The size of the vidicon camera has led to its use in certain types of broadcast applications. Some of the advantages of the vidicon camera are low operating cost, simple circuitry (which accounts for its small size), high signal-to-noise ratio (when sufficient light is available), and ease in setting up.

9-3. *Tube construction.* One reason that the vidicon camera can be constructed in a small package is that the vidicon tube is small in size. A standard vidicon tube, as shown in figure 42, is 1 inch in diameter and approximately 6 inches long. There are some smaller tubes only ½ inch in diameter and 3 inches long which are giving satisfactory results. Although the tube is small, it contains an electron gun which produces a scanning beam and a photoconductive faceplate. The faceplate is a transparent conducting material coated with a photosensitive substance a few microns thick. The electron gun which produces the scanning beam has the usual heater, cathode, control grid, and accelerating and shaping grids. Focus, deflection, and alignment of the electron beam are accomplished by the use of external coils. In some cameras the alignment coil is replaced with permanent magnets and in others no alignment method is used.

9-4. The transparent conducting material is connected to a fixed positive potential. When light strikes the photosensitive layer it becomes conductive in relation to the amount of light. A dark spot will act as an insulator, whereas a light spot becomes conductive. The photosensitive layer then takes on a pattern of positive charges, the amount of charge being directly proportional to the amount of light striking the spot. The electron beam coming from the electron gun scans each spot and neutralizes it. The current, which is a product of this neutralization, flows through a load resistor, thus developing a video signal. This signal voltage may be coupled to a video amplifier stage.

9-5. *Care and handling.* There are some precautions you should keep in mind when using a vidicon camera. Remember that as light strikes

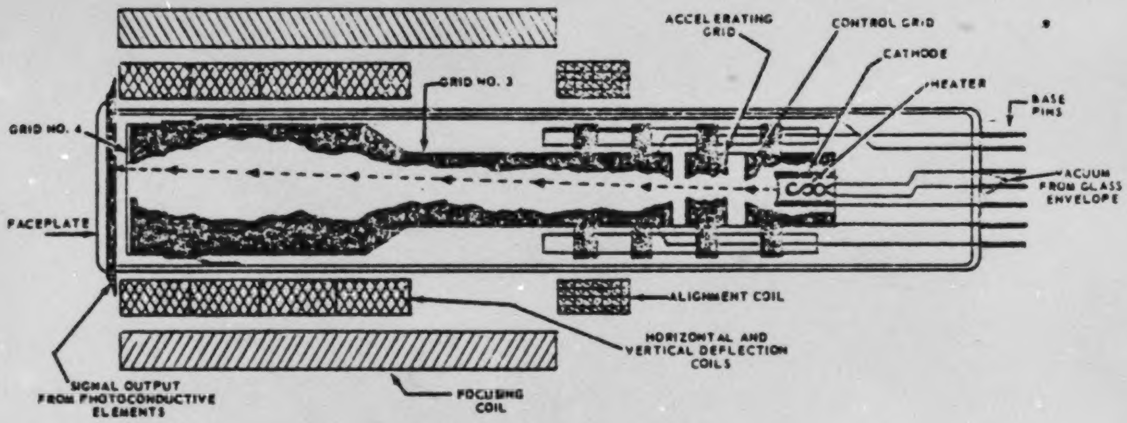

ACCELERATING GRID
CONTROL GRID
CATHODE
HEATER
BASE PINS
GRID NO. 3
GRID NO. 4
ACUUM FROM GLASS ENVELOPE
FACEPLATE
ALIGNMENT COIL
HORIZONTAL AND VERTICAL DEFLECTION COILS
SIGNAL OUTPUT FROM PHOTOCONDUCTIVE ELEMENTS
FOCUSING COIL

Figure 42. Cutaway view of vidicon tube.

the photoconductive material, current flows in proportion to the intensity of the light. If a camera is focused on a fixed spot of high intensity light, the current in the photosensitive material can cause an image burn. Any time one particular area of the photosensitive material is used more than the other areas, it leaves a burn or image when the pattern is changed; therefore, to avoid a burn pattern, you should adjust the camera scanning to utilize the maximum useful area of the photosensitive material at all times. The photosensitive material should never be exposed to an image of the sun; therefore, it is advisable to always cap the lens when a camera is being moved in or through an area where sunlight or any high intensity light is present. Another point to remember when using, handling, or storing a vidicon tube is to avoid tube positions that could cause loose particles in the neck of the tube to fall on the photosensitive area. Like most tubes the vidicon may be damaged by rough handling and abuse; always be careful when moving cameras or tubes. Operational adjustments, such as applying excessive electrode voltage, can also cause damage to vidicon tubes. Furthermore, if the beam is turned on when vertical and horizontal scans are not functioning, a spot burn can quickly damage the tube. Now that we have reviewed the major precautions to be observed when using a vidicon camera, let us discuss the operation of this type of camera.

9-6. *Adjustments and alignments.* There are a number of adjustments and alignments that are necessary before a vidicon camera can be operated. At this point we will assume that all the necessary wiring is completed from camera to monitor, that proper power is connected, and that the sync generator is connected and operating properly. If for any reason there is doubt as to the presence of either the horizontal or vertical sweep, it can be checked with a scope. After power has been applied, sufficient time for warmup (generally from 10 to 20 minutes for vacuum-tube circuits) should be allowed before the actual adjustments and alignments are made.

9-7. The initial picture on the monitor will be a circle or part of a circle that shows the photosensitive (mosaic) mounting section. If this is not visible, the beam control will have to be adjusted until a pattern does appear. This pattern should be visible even though there is not a lens or illumination present. When you have a visible pattern, proceed to make initial centering and size adjustments so that the circle is no longer visible at the corner of the picture. The camera scanning should now be adjusted for the maximum useful area of the mosaic. If the beam control is critically adjusted, you will be able to see small specks or flecks, which are small imperfections in the photosensitive surface (mo-

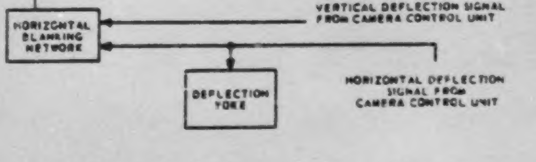

CASCODE VIDEO AMPLIFIER
TP2
VIDEO AMPLIFIER
VIDEO OUTPUT
TP3
VIDEO OUTPUT TO CAMERA CONTROL UNIT
TP1
VIDICON CAMERA TUBE
BEAM CONTROL AND VERTICAL BLANKING FROM CAMERA CONTROL UNIT
VIDICON PROTECTION SIGNAL FROM CAMERA CONTROL UNIT
VERTICAL DEFLECTION SIGNAL FROM CAMERA CONTROL UNIT
HORIZONTAL BLANKING NETWORK
DEFLECTION YOKE
HORIZONTAL DEFLECTION SIGNAL FROM CAMERA CONTROL UNIT

Figure 43. Block diagram of vidicon TV camera.

saic). If you adjust beyond this critical point, the picture will go to an all-white condition and you will lose sync stability.

9-8. Now the camera is ready to be set up for viewing an actual scene so that final adjustments can be made. It is best, of course, to use a fixed pattern such as a resolution chart. Make certain that the lens is in position and that there is proper illumination. Now center the camera lens in front of the chart and adjust the beam control to obtain a picture of the chart. The vertical and horizontal controls may require readjustment to obtain picture lock-in. Now you can adjust the lens for optical focus, and the electrical focus may also be adjusted at this time. Since there is interaction between controls, it is usually necessary to readjust each of them for the best definition.

9-9. *Block diagram analysis.* Although there are numerous variations and arrangements, figure 43 shows a block diagram of a basic vidicon camera. The inputs are from a camera-control unit which may or may not be a separate unit; this unit will be discussed later. Since the vidicon tube is the heart of the camera, we must understand its signal output. If a scope is connected to Testpoint 1 (Tp 1), a pattern similar to figure 44 should be seen. Of course, the portion representing the picture information depends upon the scene being viewed. The horizontal and vertical blanking pulses are similar to those illustrated. If the scope is moved to Tp 2, the same pattern is seen larger in amplitude. The video amplifier stage will further amplify the signal to drive a cathode follower which is used as output stage. A scope check of Tp 3 will show the pattern indicated at the other testpoints but smaller in amplitude than at Tp 2. The cathode follower circuit minimized loading effects and provides impedance matching.

9-10. **Image Orthicon Cameras.** An image orthicon camera is generally thought of as a studio camera because it is relatively large. In addition, the image orthicon camera usually will have an attached viewfinder that enables the operator to see exactly what the camera is picking up or viewing. The overall size of the camera plus viewfinder makes for a comparatively large unit which weighs approximately 100 pounds. Weight and size are being reduced by using solid-state components and printed circuits in newer models of the image orthicon (IO) camera. The IO camera has been adapted for field use where there is a need for high sensitivity or studio quality production.

9-11. *Tube construction.* It is important that you understand the IO tube construction and how it operates because the overall functioning of the camera centers around the operation of the IO tube. Figure 45 is a cutaway drawing of an IO tube. For study purposes, we have divided the IO tube into three sections—the image, scanning, and multiplier sections. The image section receives the light from a subject as it is focused on the photocathode. The photocathode emits electrons in proportion to the amount of light received from the subject. The electrons are accelerated toward the target, which is comparable to the photoconductive faceplate of the vidicon. Electrons strike the target, a glass membrane approximately .0001 inch thick, and cause secondary emission. This leaves the target with a positive charge. Since the glass target is very thin, the same charge pattern appears on the beam side, where it will be scanned. To keep the target from being burned by a stationary pattern, an orbiter coil is used to move the pattern at a rate of 1 rpm. This is not a rotation of the image, but a shifting about of the entire pattern. This precaution against image burn is something not found in a vidicon.

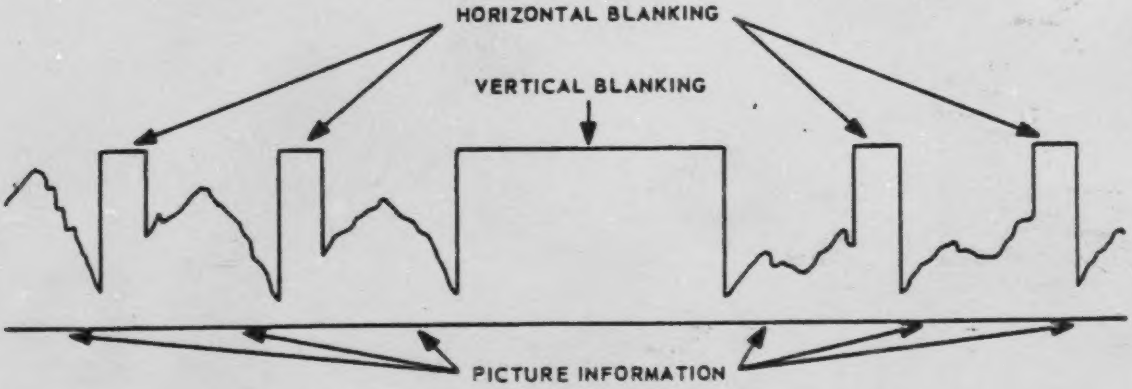


Figure 44. Video and blanking signals from TV camera tube (not to scale).

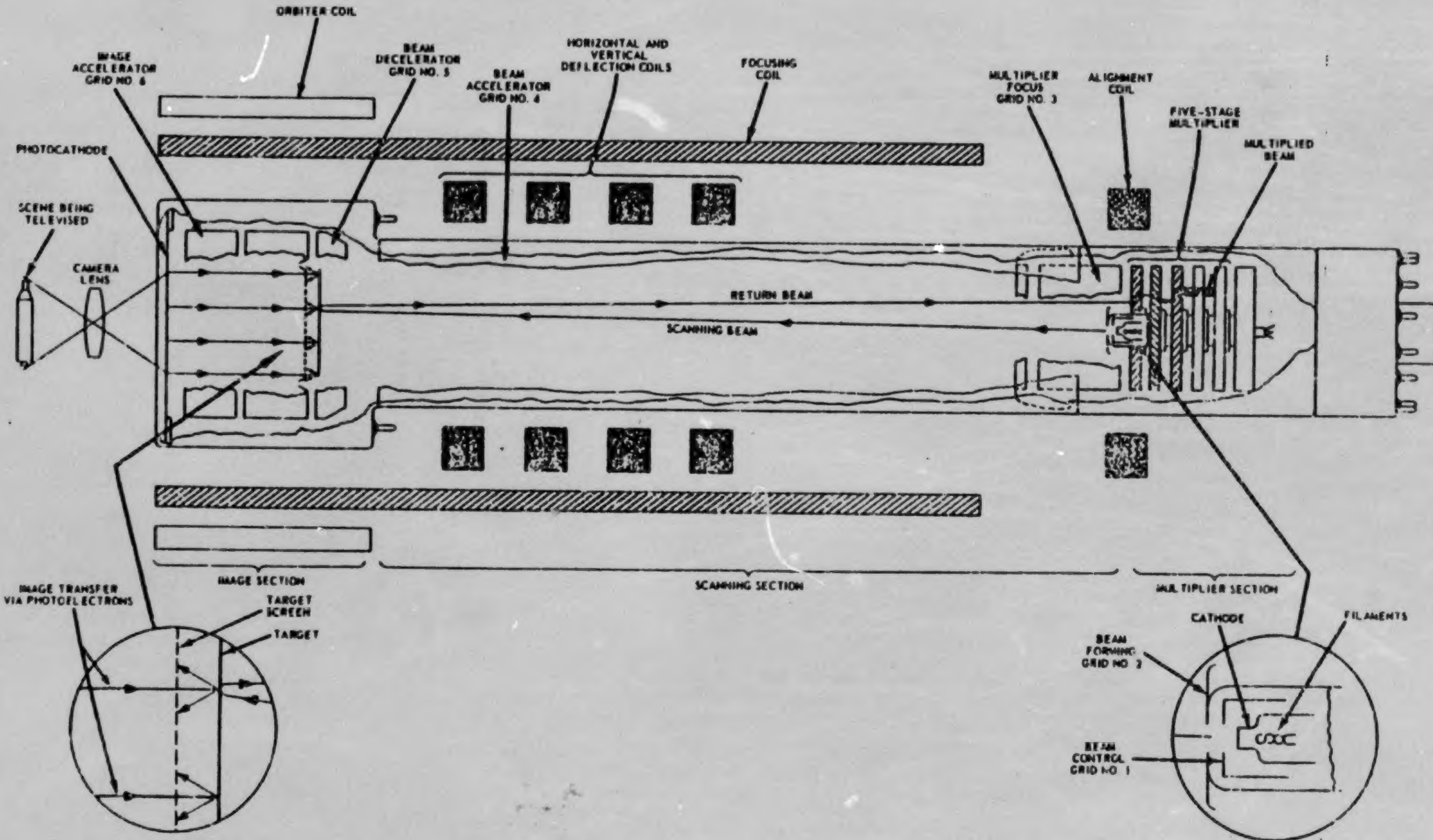

ORBITER COIL
IMAGE ACCELERATOR GRID NO. 6
BEAM DECELERATOR GRID NO. 5
HORIZONTAL AND VERTICAL DEFLECTION COILS
BEAM ACCELERATOR GRID NO. 4
FOCUSING COIL
MULTIPLIER FOCUS GRID NO. 3
ALIGNMENT COIL
FIVE-STAGE MULTIPLIER
MULTIPLIED BEAM
PHOTOCATHODE
SCENE BEING TELEVISED
CAMERA LENS
RETURN BEAM
SCANNING BEAM
IMAGE SECTION
SCANNING SECTION
MULTIPLIER SECTION
IMAGE TRANSFER VIA PHOTOELECTRONS
TARGET SCREEN
TARGET
CATHODE
FILAMENTS
BEAM FORMING GRID NO. 2
BEAM CONTROL GRID NO. 1

Figure 45. Cutaway view of image orthicon tube.

219

220

210

9-12. The scanning unit of the IO uses an electron gun similar to those used in vidicon or other types of cathode-ray tubes. The beam from the gun strikes the target and gives up electrons in proportion to the amount of positive charge on the target. The remaining electrons are returned to the electron multiplier unit. The beam position and overall intensity are controlled by the beam accelerator, the horizontal and vertical deflection coils, and the focus coils. The multiplier focus element provides additional control of the return beam, which is directed into the multiplier unit. You will recall that the vidicon does not have a return beam; its signal output is taken directly from the photoconductive element.

9-13. After the IO's return beam passes the multiplier focus and the end of the electron gun, the beam strikes the first multiplier dynode of the five-stage multiplier section. Electrons strike the plate of a dynode with enough force to cause secondary emission. The amount of multiplication depends on the number of dynodes and voltages applied. The output from the electron multiplier section will be determined primarily by the number of electrons in the returned beam. The brighter image returns fewer electrons to the multiplier stage, because it causes a greater positive charge on the target.

9-14. The IO tube has what is considered a high gain because of the multiplier unit. Since it has a high gain, it does not require a high-gain video amplifier. By comparison, since the vidicon does not have a high gain, it requires a cascode video amplifier followed by additional amplifier circuits. Since the IO tube amplifies, it is a source of noise. By contrast, the vidicon tube generates little noise but its associated video amplifiers constitute a source of noise.

9-15. *Care and handling*. The care and handling of an IO tube is important, from the standpoint of both economy and performance. Take the simple procedure of installing an IO tube. If you try to force shoulder pins into their sockets, you may damage the tube beyond repair. This means a loss of more than a thousand dollars. You should allow sufficient time for an IO tube to warm up before operating it. If the target heater is controlled manually, be careful to prevent overheating, which will cause loss of resolution and may permanently damage the tube. Also remember that new tubes should be placed in operation for several hours before they are stored to keep as spares. Moreover, all IO's that are kept as spares should be used in a camera for several hours each month to keep them free from any trace of gas. Gas may appear in a tube which is stored for a prolonged period. A word of caution about handling or moving an IO tube need be mentioned here. You should always avoid placing the tube in a position that allows loose particles in the tube to fall upon the target or photocathode. It is easy to accidentally put a tube in a near-vertical position when installing or removing it. *Do not yield* to the temptation of setting a tube down on its face; this may cause internal and external damage. When a camera is in operation, observe position precautions; do not point the camera straight down for a bird's-eye view.

9-16. A knowledge of a large number of details concerning IO tube applications is necessary to insure proper operation and optimum performance at all times. The physical orientation limitations have been discussed; however, there are other considerations which will affect the operational life of an IO tube. Operating temperatures must be maintained within limits. Target-scanning adjustment limitations must be carefully set to avoid a raster burn which would ruin the tube. A dynode spot must be eliminated by slight defocusing. An ion spot should be detected and action taken to return the tube for reprocessing. Watch for and eliminate target-screen pattern pickup. These are trouble areas which must be carefully watched.

9-17. *Performance*. The overall performance of a pickup tube is what determines the choice of a camera for a particular application. The vidicon and the image orthicon pickup tubes are the most common choices. The vidicon has found wide application in fields other than studio work; however, the IO is used almost exclusively in studio applications. The following comparison of the vidicon and IO will give you an idea of the advantages and disadvantages of each tube.

Vidicon	*Image Orthicon*
1. Operating cost is approximately $0.10 per hour.	1. Operating cost is approximately $2.00 per hour.
2. Average output signal level is approximately 15 millivolts.	2. Average output signal level is approximately 50 millivolts.
3. Output signal level is subject to change with varying light levels.	3. Output signal level is stable over a wide range of light levels.
4. Low tube-noise characteristics result in an excellent signal-to-noise ratio at a light level of approximately 200 foot-candles. (Ratio—300 to 1).	4. Inherent tube noise limits the signal-to-noise ratio at all light levels. (Average ratio—40 to 1).

Vidicon	*Image Orthicon*
5. Picture smear results when uncontrollable, fast-moving objects are being televised.	5. Picture smear is not a problem when fast-moving objects are being televised.
6. Simple external circuitry results in small, inexpensive cameras.	6. Detailed, complex circuitry results in large, expensive cameras.

9-18. The vidicon and IO tubes are both widely used; picture quality is the scale of comparison. The IO tube pickup ability is comparable to photographic film with an American Standard Association (ASA) Speed or Exposure Index of approximately 8000, with some rated as high as 10,000. This speed, plus the spectral response approaching that of the human eye, makes this an ideal tube for camera use where light levels range from deep shadow to bright sunlight. Although the present vidicon tubes produce high-quality pictures only if there is sufficient light, they are being improved so that they can attain studio quality performance at relatively low light levels. Furthermore, experimental work is being done to develop the vidicon for wider use with color cameras. Research is being conducted to explore the possibility of developing an IO or similar tube that can pick up all three colors. If such a tube is developed, a single tube would replace the three IO tubes used in present-day color cameras.

9-19. *Adjustments and alignments.* This section will not give you any specific adjustments or alignments for a camera because the Air Force purchases off-the-shelf items from various companies. However, there are some general guidelines to be followed when making adjustments on cameras. Just as in the section on care and handling, we will present information pertinent to pickup tubes. For all of the items discussed in this section, you must refer to the instructions manual of the particular camera for specific details. The simple process of mounting a camera on a pedestal requires an adjustment in the mounting position for the best balance. If you change lenses or add more lens units to a turret, you will have to rebalance the camera.

9-20. Since you have already studied the care and handling of the IO tube, let us assume the lens turret has been removed, and the IO has been removed and replaced. When you replace the lens turret or other lens assembly, do not overtighten, yet be sure to tighten the turret retainer(s) enough to prevent any lens rocking. If it becomes necessary to remove any of the coil assemblies in a camera, you may have to partially remove an assembly to gain access to retaining springs and clips which hold plug-in jacks. The bellows of the blower must be carefully removed. In some cameras, you will have to turn the assemblies to a certain position to get to

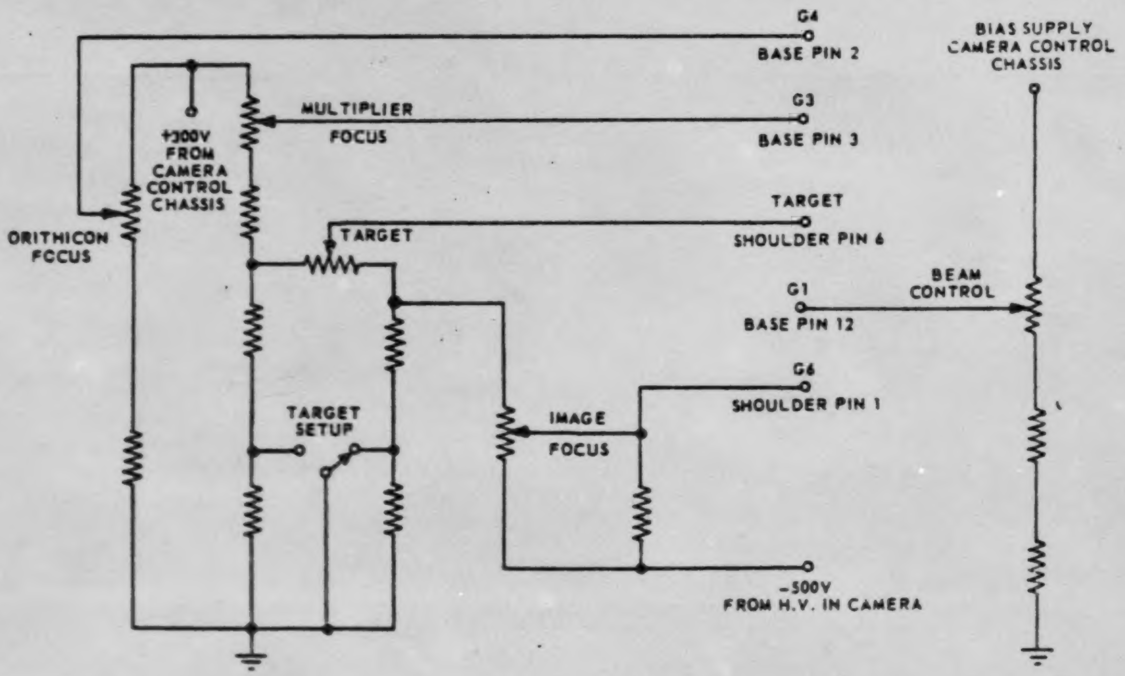


Figure 46. Controls on camera control unit.

the plugs. If at any time you are required to remove or unsolder any leads, you should label each one before removal to prevent any mixup.

9-21. Since operating temperatures must be maintained within limits, heaters and blowers are used. A motor must be oiled on schedule, as recommended by the manufacturer, for satisfactory performance and maximum life. When installing a new motor, you should check manufacturers instructions as to oiling it before operating. Of course, be certain that the bellows are properly installed; cooling will be impaired if the airflow is misdirected.

9-22. Once the mechanical adjustments are made on the camera, the electrical adjustments can be made. Before you make any electrical adjustments, the camera (with a standard IO tube) should be turned on and allowed to warm up for one-quarter to one-half hour with the lens capped. Read the instructions carefully and follow them closely when you uncap the lens and adjust grid No. 1 (beam adjust on camera control). An improper procedure can cause permanent damage to the IO tube, since a cold photocathode target will retain a permanent image.

9-23. During the warmup time, you must check to determine that the deflection circuits are functioning properly and that the beam is "overscanning" the target. Overscanning the target prevents burning the target with a smaller than normal raster. After warmup time, set the target voltage at approximately 2 volts negative and adjust grid No. 1 voltage (beam control on the camera control unit) until a rough-textured picture of No. 1 dynode appears on the monitor. A very slight adjustment of the target voltage may be necessary; if so, this adjustment also is made at the camera control. Now you are ready to check the alignment coil current by moving the orthicon focus control (voltage on grid No. 4) back and forth. If the alignment coil current is not set correctly, the dynode spot will move up and down or back and forth. However, if the current is correct, the spot will just go in and out of focus. Always keep the beam current as low as possible during test and operational service to obtain the best picture quality and to minimize tube noise.

9-24. At this point, uncap the lens, open the iris, focus on a test pattern, and proceed to make voltage and current adjustments by means of the camera controls (target and beam) located on the camera control unit. The target voltage is slowly increased until you just see the test pattern. The target voltage should be increased along with the beam current to obtain the best and most uniform shading and low noise. The actual amount of voltage increase will depend on the brightness and contrast of the scene being televised. An adjustment of grid No. 5 (beam decelerator) should now be made to obtain the most uniform shading from the center to the edge of the picture. Next, adjust grid No. 3 (multiplier focus) for maximum signal output. Grid No. 6 (image accelerator) may now be adjusted to produce a sharply focused straight line on the monitor; if it is out of adjustment, the pattern will be slightly S-shaped.

9-25. The adjustments just described are rough settings that will require refinements which vary somewhat depending on the camera or camera tube used. Figure 46 is a diagram of a voltage divider circuit and the controls necessary to provide the voltages for an IO tube. You will notice a voltage spread from +300v to −500v which provides voltages to four controls. Notice that the −500v is derived from the HV power supply in the camera. The No. 1 (beam control) picks up bias voltage from the bias rectifier in the camera control unit.

9-26. Other electrical adjustments to be made are the alignment coil current and focus current. The coil current provides magnitude and direction of the magnetic field around the coil. Alignment controls are normally found on the camera, but the current is derived from a separate power supply. The focus coil is a single coil which receives current from a current regulated power supply. (This power supply is located on a separate chassis and is usually rack-mounted.) The orbiter coil is not adjustable, but can be switched on or off. The coil is a protective feature and should be used at all times. If the target heater is used for quick warmup, be sure and turn it off when operating temperature is reached; otherwise, the target may be damaged. This is true if the heater is not thermostatically controlled as in some cameras.

9-27. *Diagram analysis and troubleshooting.* Assume that we are checking a camera that is functioning properly and that we are doing this to become familiar with all of the correct waveshapes. You know that the scanning beam is accelerated to the target by the tube elements; however, before the return beam will give us any information or intelligence, it must scan the target. You recall that the target scan must be in an orderly manner or sequence; therefore, we must control the position of the beam at all times. This control is provided by the horizontal and vertical deflection coils. The deflection voltages which are fed to these coils are usually generated within the camera but they are triggered by pulses from the camera control (which will be discussed in the next section). These pulses

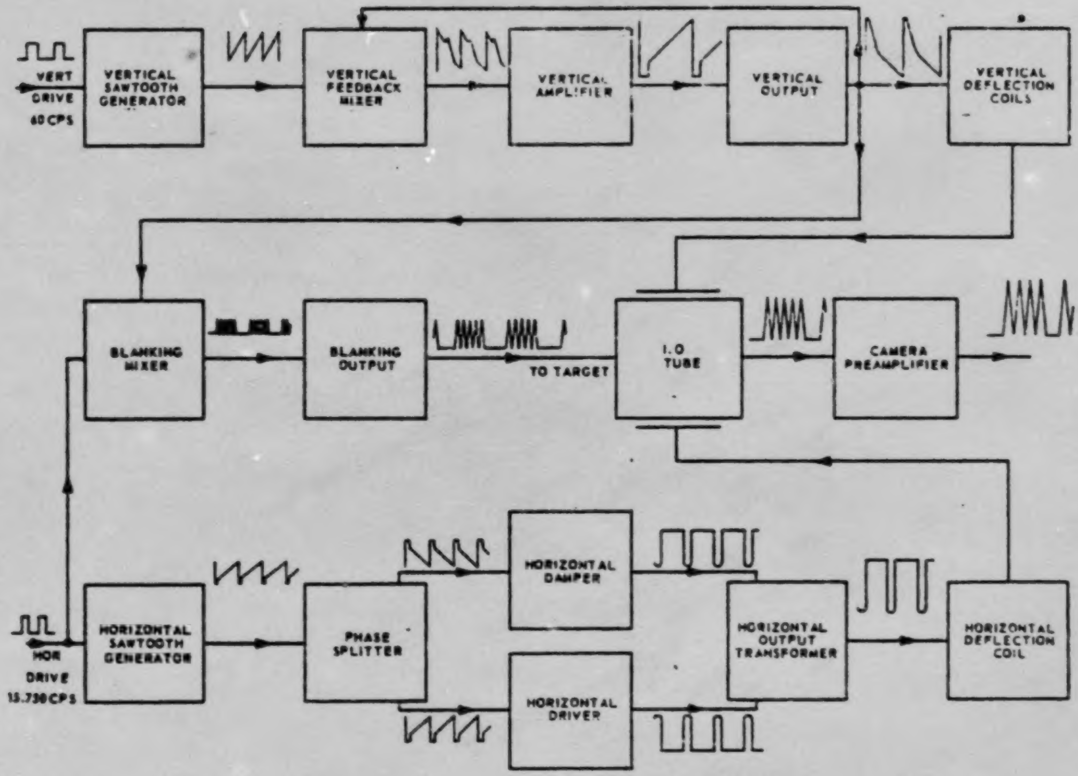

VERT
DRIVE
60 CPS
VERTICAL SAWTOOTH GENERATOR
VERTICAL FEEDBACK MIXER
VERTICAL AMPLIFIER
VERTICAL OUTPUT
VERTICAL DEFLECTION COILS
BLANKING MIXER
BLANKING OUTPUT
TO TARGET
I.O TUBE
CAMERA PREAMPLIFIER
HOR
DRIVE
15.750 CPS
HORIZONTAL SAWTOOTH GENERATOR
PHASE SPLITTER
HORIZONTAL DAMPER
HORIZONTAL DRIVER
HORIZONTAL OUTPUT TRANSFORMER
HORIZONTAL DEFLECTION COIL

Figure 47. Simplified block diagram of image orthicon camera.

originate in the sync generator. Figure 47 is a block diagram showing basic sections and waveforms necessary to produce a video output from the camera to the camera control.

9-28. For a typical camera, vertical deflection is accomplished in the following manner. The vertical drive pulse from the camera control is coming in at a 60-cps rate and triggers the vertical sawtooth generator. This signal is amplified by a number of stages to drive the vertical deflection coils. As indicated by the diagram, a signal is fed back to the vertical feedback mixer; thus, the signal is reinforced and linearity is improved. A signal is also sent to drive the blanking mixer which combines the blanking pulse of both the vertical and horizontal sweep signals. A point which is sometimes missed in the study of the vertical deflection system is the direction of scan. We study the scanning of the picture tube in a monitor and find it is from top to bottom; however, the camera tube normally scans from bottom to top. By using a bottom-to-top scan, we can use an off-the-shelf camera lens with the TV camera. There are times when we want to scan from top to bottom such as when we project a film image directly on the camera tube, in which case the image is right side up. Therefore, if a camera is to be used for both purposes, it is necessary to reverse the direction of scan. On some cameras, there will be a switch to reverse the direction of scan. It may be marked as scan reversal, normal/film, or in some other manner to indicate the direction of scan. A reversal of scan requires only that the polarity of the vertical deflection coils be reversed. Vertical centering is accomplished by applying a voltage across the deflection coils; however, this is a voltage which can be varied. If the camera is designed for reverse scan, it will probably have two centering adjust controls which can be preset for both directions of scan.

9-29. Using a scope to signal trace through the various stages of a camera, you will see waveforms similar to those shown in figure 47. However, for a particular camera adjustment, you should refer to the specifications for that camera. The number of waveforms and their configurations will be determined by the number of stages necessary to achieve signal amplification. With a bit of thought, you should be able to reason out the signal shape at the various places in the diagram.

9-30. You remember that the horizontal drive pulses are coming in at a frequency of 15,750 cps. This gives the standard ratio of 262 − ½ horizontal sweeps to 1 vertical sweep. Since the horizontal pulses are at a higher frequency, they require more shaping; therefore, the drive pulses trigger a sawtooth generator which drives a sawtooth phase splitter. Notice that the phase splitter has two output signals that are 180° out of phase with each other. These two signals drive two separate stages—a driver and a damper. The primary of the output transformer is so connected that the output signals of the driver and damper are added and thus reinforced to give a strong sweep signal out. The output from the transformer goes to the horizontal deflection coils to the IO protection circuit and the HV pulse amplifier which drives the HV rectifier. Depending on the type of camera, the pulse distribution may be sent to additional points, such as a preamplifier.

9-31. Once the vertical and horizontal deflection voltages are generated and applied to cause the beam to scan the target image, a video picture signal is generated. This signal is amplified by the video preamplifier section which may be composed of a number of stages. The preamplifier section may be built into the camera or it may be a plug-in unit; in any case, it serves to strengthen, shape, and compensate the signal. It is designed to give an overall high-quality response. Its output goes to the viewfinder and via cable to the camera control unit. A block diagram of the preamplifier is not included because the signal waveforms are essentially the same throughout; what variations there are may be peculiar to the particular camera.

9-32. Troubleshooting a camera with a scope is relatively easy so far as locating the stage or basic circuit is concerned. For example, if you had a straight horizontal line on the viewfinder, you would immediately check the deflection circuits. After you had determined that the deflection circuit is not faulty, you would simply check the output of the stages until you located the trouble. Having located the stage, the scope could be used to find the point in the stage where the signal was absent or improper. As you gain experience, you will recognize linearity distortion and know exactly where to look for the trouble. If it is vertical linearity, the trouble is probably in the feedback circuit. Suppose the horizontal linearity is poor; you would check the waveforms of the horizontal circuits. If you find from the indications that there is no sufficient blanking signal, you should immediately check the blanking circuits with a scope to determine if the signal is absent or just weak. When a trouble is noticed on a monitor, for example the viewfinder monitor on the camera, you must not immediately assume that the camera is at fault. The more experienced maintenance man will always know to compare the viewfinder with the camera control monitor and perhaps with a line or utility monitor. The camera control has a built-in scope that can be used as an aid to troubleshooting. Picture monitors and the built-in scopes will be discussed in the next chapter, but let us look now at camera control unit and its controls.

10. Camera Control

10-1. We have chosen to discuss the IO camera control because an understanding of it will enable you to maintain other camera control consoles. Earlier, you were made aware of a number of controls that are located on the camera control. In addition to the controls related to the camera, the control unit performs the necessary steps to obtain a composite television signal.

10-2. **Functions.** Including controls and circuits, we can list six basic functions that can be performed by the camera control unit.

- Remote adjustment of the various voltage potentials necessary to the operation of the IO camera.
- Correction for shading.
- Correction for black and white compression.
- Provision for signal amplification to the level required for transmission.
- Adjustment for proper blanking and black level.
- Addition of sync pulses in a simple system. (In a complex system, the sync pulses are added in the switcher, which will be discussed in the next numbered section.)

10-3. *Operational adjustments.* The remote adjustments of the various voltage potentials necessary to operate the IO camera were discussed in the previous section under the heading *Adjustments and alignments* and illustrated in figure 46. The adjustments we will consider here have to do with the picture shading and black-to-white fidelity. You must realize that it takes two maintenance men to set up a camera properly, one man on the camera and one on the camera control. They must be able to talk clearly and work together to get a good video signal.

10-4. The camera control amplifies a video signal coming from the preamplifier in the camera; meanwhile, other things are also happening. (see fig. 48). While the video signal is

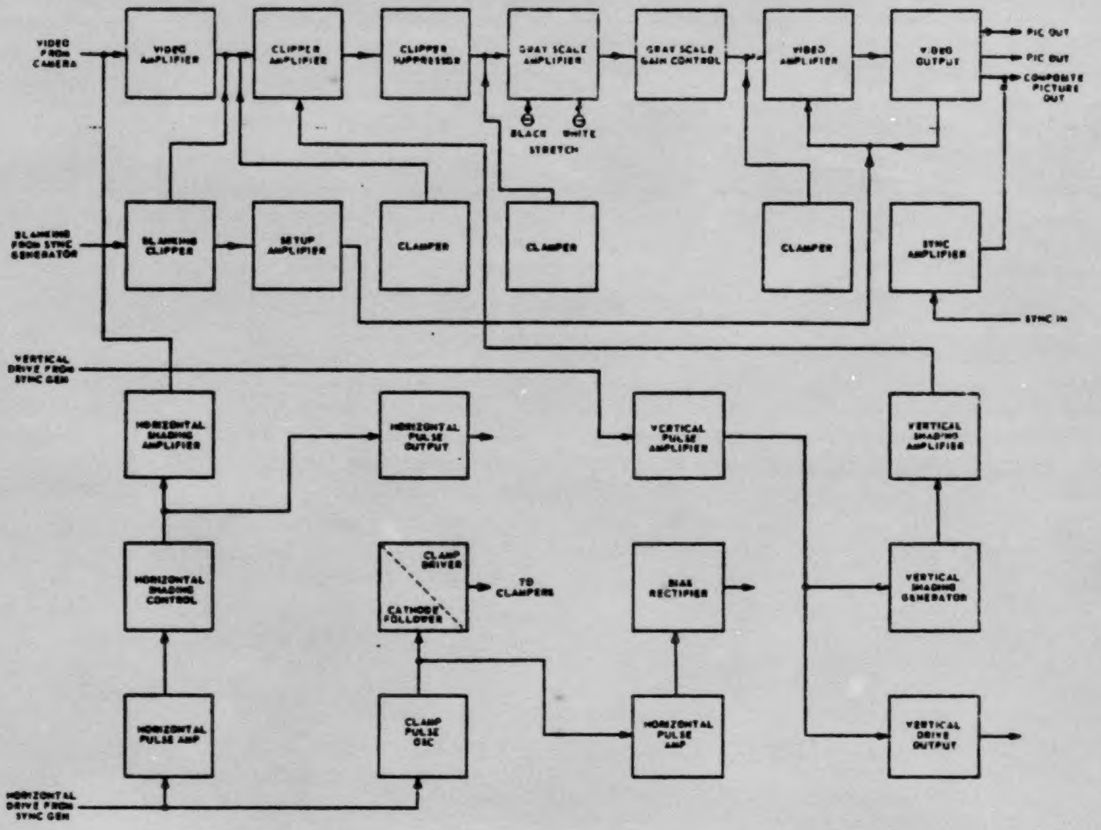

VIDEO FROM CAMERA
VIDEO AMPLIFIER
CLIPPER AMPLIFIER
CLIPPER SUPPRESSOR
GRAY SCALE AMPLIFIER
GRAY SCALE GAIN CONTROL
VIDEO AMPLIFIER
VIDEO OUTPUT
PIC OUT
PIC OUT
COMPOSITE PICTURE OUT
BLACK
WHITE
STRETCH
BLANKING FROM SYNC GENERATOR
BLANKING CLIPPER
SETUP AMPLIFIER
CLAMPER
CLAMPER
CLAMPER
SYNC AMPLIFIER
SYNC IN
VERTICAL DRIVE FROM SYNC GEN
HORIZONTAL SHADING AMPLIFIER
HORIZONTAL PULSE OUTPUT
VERTICAL PULSE AMPLIFIER
VERTICAL SHADING AMPLIFIER
HORIZONTAL SHADING CONTROL
CLAMP DRIVER
CATHODE FOLLOWER
TO CLAMPERS
BIAS RECTIFIER
VERTICAL SHADING GENERATOR
HORIZONTAL PULSE AMP
CLAMP PULSE OSC
HORIZONTAL PULSE AMP
VERTICAL DRIVE OUTPUT
HORIZONTAL DRIVE FROM SYNC GEN

Figure 48. Block diagram of camera control unit.

being amplified, it may lose its d-c component; the clamper circuits restore it. To further increase the overall flat response for the wide band of frequencies (approximately 8 mc), it is necessary to use frequency-compensating circuits and degenerative feedback.

10-5. Blanking signals from the sync generator are fed into the blanking clipper, which is coupled to the output of the video amplifier, thus adding blanking to the video signal. Another output of the blanking clipper is used as an input for the setup amplifier. This is a cathode follower stage which is coupled to one of the final video amplifier stages. A definite relationship is therefore established between signal black and reference black. Notice that the sync signal is not inserted until the final output, and then to only one of the output points.

10-6. *Shading and stretch circuits.* Shading signals are also added at the video amplifier to compensate for horizontal or vertical shading. Some shading compensation is added in the camera; however, to improve the picture, more shading compensation is inserted in the camera control video amplifier. The horizontal shading is inserted at the input of the first video amplifier, whereas the vertical shading is inserted at the cathode of the clipper amplifier. The shading signal can be varied until it is equal in amplitude but opposite in phase to any spurious horizontal or vertical shading signals which may be present; thus, any undesired shading can be canceled.

10-7. As already mentioned, the controls are initially adjusted when the camera is set up at the start of the day, with the exception of screwdriver adjustments which are set up and left alone. On most of the camera control units, the only time that you need to readjust the screwdriver-type controls is when you change tubes or a tube deteriorates. There are other controls (fig. 49) that are adjusted from the camera control console after the camera is all set up and operating. Before these controls can be adjusted, the camera must be operating and focused on a scene: if the scene is normal, the switches will be in the normal position. If the scene is mostly white, S1 and the white stretch switch S2 will be put in the stretch position; if it is a dark scene, S1 and the black stretch switc

S3 will be placed in the stretch position. The stretch circuits adjust the point of operation up and down the characteristic curve of the tube. The white stretch circuits amplify the white scenes which were compressed due to the characteristics of the IO tube. The black scenes are amplified to correct for the black-scene compression, which will normally take place in a kinescope. Therefore, with this correction made, the scene being viewed will be displayed correctly. The corrections made by the stretch circuits increase the amplitude of the signals above the standard levels; therefore, the gray scale gain control circuit is incorporated to afford an adjustment back to the standard video level.

10-8. **Trouble diagnosis.** With the preceding discussion still in mind and using figure 48 as a reference, what stage(s) would you check first if you found that your predominently white scenes looked more gray than white? Your first action should be to use the white stretch control. If this does not correct the problem, then you should check the gray scale amplifier circuit and then proceed to check the white stretch circuit (operation of switches and voltage dividers). If the black scenes seemed to be washed out, you should check the same amplifier and the black stretch circuit. If you notice blanking signals appearing on the control monitor but not on the viewfinder, you should check the blanking clipper. Other determinable troubles are caused by loss of drive to the vertical and horizontal deflection circuits. Such troubles produce symptoms that lead you to check the associated amplifier circuits. When there is a loss of bias voltage, you need to check the bias rectifier circuit or the preceding horizontal circuits. It is important to realize that your troubleshooting speed depends in large measure upon your ability to reason through a problem and also upon your understanding of this equipment.

10-9. Not all camera control units are console-mounted. There are also field-type units The field units perform the same basic function as the console units and the circuits are about the same. Their function controls are located on the outside of the unit. However, those controls that are associated with the adjustment of the pictur and waveform monitor are usually located in le convenient places, such as recessed panels on the top or sides. These controls will be placed and grouped differently on the field unit because they are designed for portability.

11. Switchers and Video Amplifiers

11-1. In a complex system, a switcher may be a sophisticated piece of equipment. We will consider the functions it can serve and describe the manner in which they are accomplished. A switcher contains video amplifiers which, as you know, are used extensively throughout a TV system. Therefore, our discussion of video amplifiers will be broad in scope and applicable to virtually all equipments employing them.

11-2. **Switchers.** Switching equipment is necessary in all but the simplest television installation.

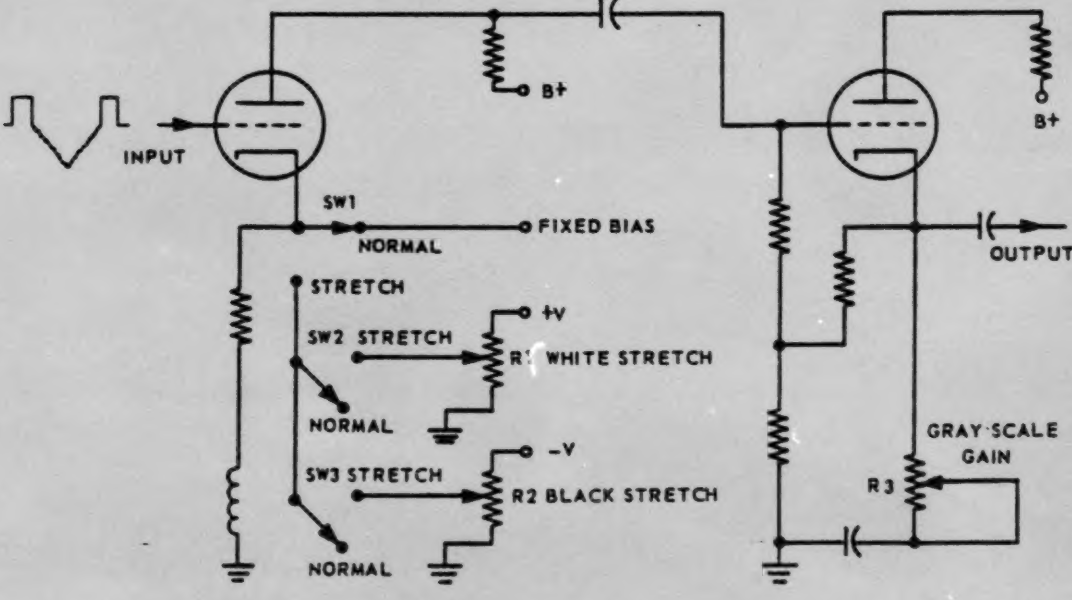


Figure 49. Schematic of stretch and gray scale circuit.

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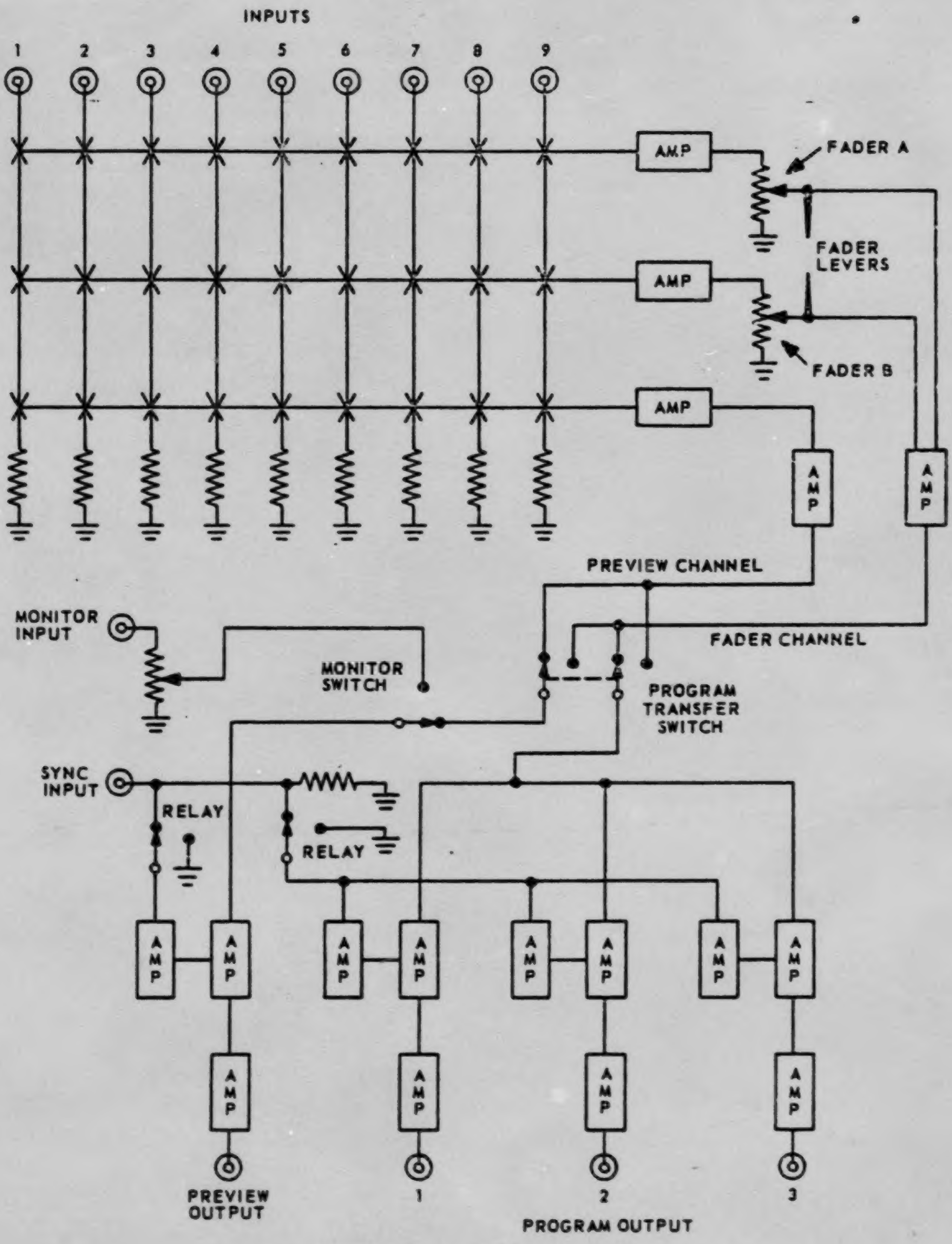

INPUTS
1
2
3
4
5
6
7
8
9
AMP
FADER A
FADER LEVERS
AMP
FADER B
AMP
AMP
AMP
PREVIEW CHANNEL
FADER CHANNEL
MONITOR INPUT
MONITOR SWITCH
PROGRAM TRANSFER SWITCH
SYNC INPUT
RELAY
RELAY
AMP
PREVIEW OUTPUT
1
2
3
PROGRAM OUTPUT

Figure 50. Block diagram of a typical video switcher.

It functions so that the video output from one of several television signal sources can be selected and sent to one of several outgoing paths in a distribution system. In a complex closed-circuit application, switching equipment is set up to also provide for program monitoring and previewing; video switching between studio cameras, film cameras, and remote pickups; and special effects such as fading and lap dissolving.

11-3. Video switchers, which may operate either directly or remotely by relay, employ pushbutton switching. Zero time interval during the transfer would be ideal, but since this is impractical, switchers are designed to effect the transfer in one of two ways, either gap switching or overlap. For camera switching, a slight overlap is generally introduced; the second signal is switched in before the first is removed. This double termination, or make-before-break, prevents undesirable flashes and avoids black areas. For preview monitors, however, and for master control switching between programs, the transfer is made over live lines, and gap, or break-before-make, switching is employed. Both the gap and the overlap methods permit video transfer with a minimum of picture disturbance.

11-4. *Block diagram analysis.* Switching equipment, in addition to making the signal transfer, also performs several other functions. Synchronization is inserted, and the transfer is smoothly made with fade-ins and fade-outs, lap dissolves, or such special effects as diagonal wipes. Or, instead of switching, two signals may be superimposed (as when titles are flashed over a picture), or mixed in split-screen montages. Furthermore, there are provisions for previewing the video and monitoring the output line.

11-5. The switching equipment, to perform these various tasks, includes the following components: the basic switching unit, or relay chassis; the fader assembly; isolation and gain stages; special effects and lap-dissolve amplifiers, which may be fed back to the video input for previewing before switching; and mixing or output amplifiers, where synchronization is added.

11-6. Figure 50 is the block diagram of a versatile switcher with a number of inputs; some are for local, noncomposite inputs (studio and film cameras), and others are for composite or noncomposite inputs from remote sources or from additional local cameras. In addition, the preview channel contains an input which is used for monitoring the line or off-the-air signal. Note that the program transfer switch permits the preview channel to be used for the program output while the two fader channels are being used for the previewing output to preset lap dissolves, fades, or superpositions. The signal is strengthened and isolated for distribution by video amplifiers. These amplifiers will be studied subsequently.

11-7. Suppose that you have a camera signal to input 1 of figure 50. The signal could be selected from fader A or fader B for amplification in the fade channel. From the program transfer switch to the preview output or the program output, it picks up the sync signal. Since this is a camera signal, the sync input is necessary for inserting the sync pulses prior to transmission. The monitor input is used when a composite video input is obtained from a receiver or picture monitor. Observe that this input can be transferred to the preview output or to the program output.

11-8. There are complicated switchers composed of standard relay racks with pushbutton panels suitable for a more complex video switching system. They are designed for use in a studio control room or a master control room and can be set up to handle from six to twelve inputs and from two to six outputs. Automatic circuits which insert the local synchronizing signal permit the handling of remote inputs, and the addition of a panel of jacks and video patch cords provides rapid and efficient output distribution. The pushbutton panels may be housed in any remote location convenient for program monitoring, and the relays which accomplish the actual switching may also be located where most convenient. This permits full flexibility in station layout, and simplifies the addition of studio facilities to handle expanded operations. Even a modest or simple installation should be planned and equipped with regard to possible future expansion in order that discarded facilities and additional cost will be kept to a minimum.

11-9. *Trouble diagnosis.* Normally the switcher is regarded as a trouble-free piece of equipment. Perhaps from your own experience you have drawn this conclusion. Although few troubles occur in a switcher, they do occur occasionally; therefore, it will be much easier to quickly troubleshoot and repair a switcher if you know some probable troubles. Again referring to figure 50, suppose that you punch up a preview of number one input and you get a very good picture. However, when you punch it up on fader A, you cannot get a program output monitor picture. This is assuming, of course, that the fader control is moved in the "in" position. But, when you go to fader B, you get a picture; thus, you draw the conclusion that a bad amplifier or a bad switch contact can be the trouble. The next logical step is to check another input to fader A and see if you get a picture. If you do get a picture, the amplifier

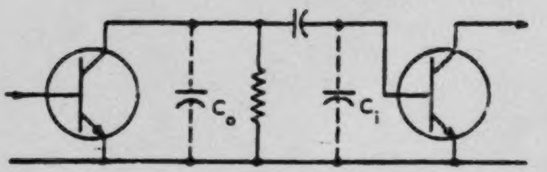


Figure 51. Simplified a-c circuit of RC-coupled amplifiers showing shunting capacitances.

is good; you should then check continuity from input 1 to the amplifier. Since the switches can cause trouble, you must observe the relationships of the various switches. The trouble can possibly be the result of one or more faulty switches. If the trouble is in a switch, it will usually be indicated by picture noise or erratic operation. Many times this trouble can be eliminated by cleaning the switch contacts.

11-10. **Video Amplifiers.** You know from previous training that video amplifiers are wideband amplifiers with a frequency range extending from a low value of cps up into the megacycles. These amplifiers are used extensively throughout a TV system. They are found whereever there is a requirement to amplify a complex waveform.

11-11. *Types.* Performance characteristics of video amplifiers depend in large measure upon the type used. Three common types are picture signal (or vision), isolation (or utility), and pulse. Their names are indicative of their function and application. Picture signal amplifiers must have a sufficiently wide band to handle the frequencies necessary for good picture fidelity. Such amplifiers are found wherever it is necessary to strengthen the picture signal. Recall that such amplification is accomplished in the camera. Monitors, which are covered in the following chapter, also incorporate many stages of this type of amplifier. Both isolation and pulse amplifiers are used for distribution purposes. In such cases, they are called DA's (distribution amplifiers). Isolation amplifiers are designed for very broad response (up to 8 mc or more), but have comparatively low gain. They serve primarily as buffers to isolate one video circuit from another and are located at junction points in a video distribution network. The pulse amplifier is employed for pulse distribution; e.g., from the sync generator to various camera units. Also, many are used within equipments for pulse amplification. Their bandpass response and characteristics depend upon the pulse shape they must strengthen or reproduce.

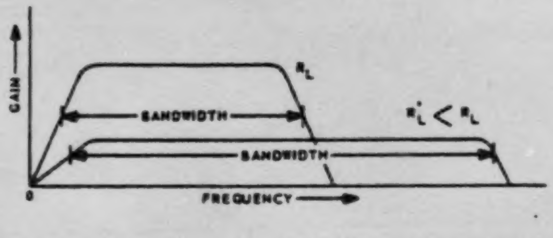


Figure 52. Effects of load resistance on frequency response of an RC-coupled amplifier.

11-12. *Broadening bandwidth.* Because the means of broadening the frequency response of transistor amplifiers is identical in principle with that of electron-tube amplifiers, our treatment will be for the most part a review. Nevertheless, it should make you mindful of the distinctive design of video amplifiers and aware of the fact that transistor amplifiers can be so designed. We will discuss matters pertaining to frequency response limitations, and broadening bandwith for wideband signals.

11-13. Any type of coupling, except direct coupling, causes the low frequencies to be attenuated and shifted in phase. Resistance capacitance (RC) coupling causes a certain amount of trouble at the low end of the band mainly because the reactance of the capacitor increases as frequency decreases. Since it is in series with the input to the succeeding stage, this reactance causes gain losses and time delays for low frequencies. Unless very low frequencies are required, however, the coupling capacitance can generally be made large enough to minimize these effects. Thus, RC coupling poses no serious limitations to low-frequency response. On the other hand, impedance coupling and transformer coupling do. These latter types are inherently poor for low-frequency amplification because the load impedance decreases and becomes more and more inductive as frequency decreases. This causes appreciable frequency and phase distortion.

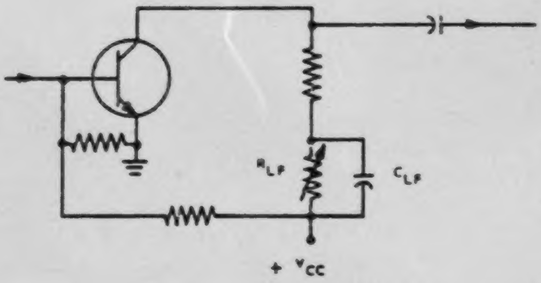


Figure 53. Low-frequency compensating circuit.

11-14. The transistor itself has a great deal to do with high-frequency response; its alpha cutoff frequency and internal capacitances are limiting factors. It should have very low internal capacitances and its alpha cutoff frequency should be well above the required upper limit of response. Special high-frequency types are most suitable for video applications.

11-15. Shunting capacitances are shown in figure 51 as output capacitance C_o and input capacitance C_i. These capacitances are made up of the transistor's internal capacitances plus wiring and stray circuit capacitances. C_o and C_i are in parallel with the load; so the higher the frequency, the lower the load impedance. Consequently, frequency distortion and phase distortion become worse with increasing frequency.

11-16. Because of these frequency-response defects, it is not possible to achieve the frequency response necessary for video-signal fidelity unless modifications are made. Let's give our attention, therefore, to the ways in which bandwidth can be extended.

11-17. Like an RC-coupled electron-tube amplifier, an RC-coupled transistor amplifier can be designed to handle video signals satisfactorily. The curves in figure 52 show that reducing the value of load resistance (R'_L is less than R_L) gives a much broader response. This broadening is acquired at the cost of overall gain. Note also that the low-frequency response is sacrificed somewhat. Gain can be improved by using additional stages, but there is no improvement in low-frequency response. In fact, it is depreciated. Moreover, to reduce the load resistance beyond a certain point is impractical and costly. Therefore, in addition to having a comparatively small value of load resistance, an RC-coupled video amplifier often contains frequency-compensating circuits to extend its response over the required range.

11-18. The parallel arrangement of R_{LF} and C_{LF} shown in figure 53 constitutes a low-frequency compensating circuit. Capacitance C_{LF} is of such a value that it is virtually a short circuit to midfrequencies and high frequencies, but it offers increasing reactance to low frequencies; the lower the frequency, the greater the reactance. Therefore, only the low frequencies are affected. The proper combination of R_{LF} and C_{LF} raises the gain and causes phase shifts which compensate for the attenuation and phase distortion caused by the coupling capacitor C. As a result, uniform response is extended to include the desired low frequencies.

11-19. Although all shunting capacitances that attenuate high frequencies cannot be eliminated, their undesirable effects can be. This is done by means of resonant peaking circuits which use the shunting capacitances. High-frequency compensation can be achieved by shunt, series, or series-shunt peaking.

11-20. Note in figure 54,A, that the inductor L is in shunt with C_o and C_i. Such an arrangement is called shunt peaking (or shunt compensation). The inductance of L goes into parallel resonance with the shunting capacitance, thereby increasing the load impedance at high frequencies (see fig. 54,C) and widening bandwidth, as shown.

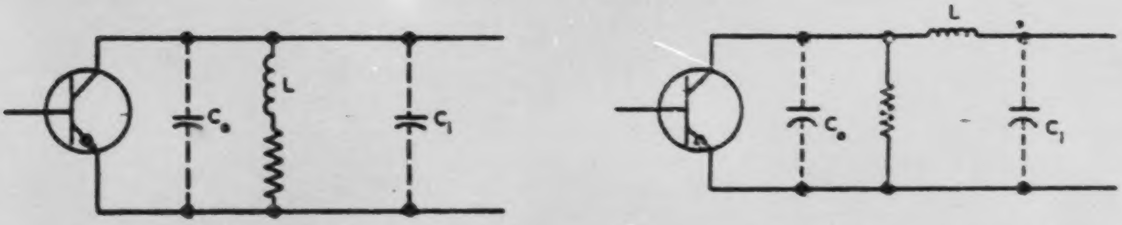
11-21. Series peaking (or series compensation) uses an inductance to form a series resonant circuit with C_i (see fig. 54,B). As resonance is approached, the current through C_i increases and compensates for the loss of gain caused by C_o. Frequency response is approximately the same as that for shunt peaking; this is also illustrated by figure 54,C.

11-22. Figure 55 shows a video amplifier that employs shunt-series peaking and low-frequency compensation. The type(s) of compensation and the amount necessary depend largely upon the application and the bandwidth of the video signal.

11-23. Another way to broaden bandwidth is by means of feedback. Knowing that degenerative feedback reduces all types of distortion, it is not surprising to find this type of feedback widely used in transistor video amplifiers to extend bandwidth and improve fidelity. Either part or all of an emitter resistor can be unbypassed to provide degenerative action. This method differs in no way from that used in electron-tube amplifiers. In fact, the CC amplifier (also called an emitter follower) corresponds to a cathode follower. Both the emitter follower and cathode follower are, in essence, video amplifiers that use a maximum amount of degenerative feedback (the entire output signal voltage is fed back to the input). Although no voltage gain can be realized, the follower does give current and power gain and is most useful for matching a high impedance to a low impedance.

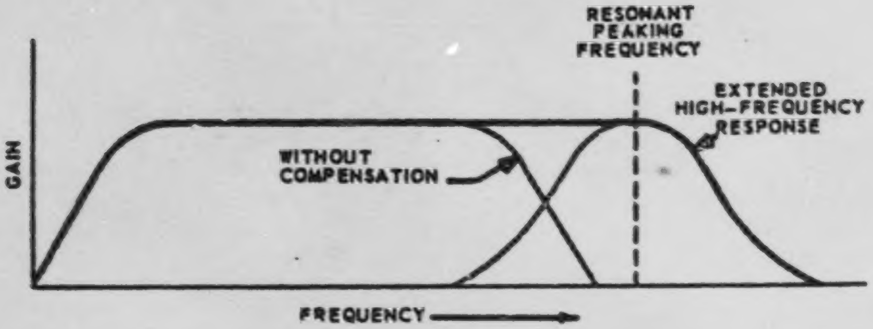
11-24. A true emitter follower (CC amplifier) has no impedance between the collector and a-c ground. If a resistor of low value is inserted in the collector circuit, a voltage gain can be obtained by taking the output from the collector. Actually, this amounts to having a CE amplifier with emitter follower action. By properly proportioning the collector and emitter resistors, the amplifier can be made to suit many video applications.

11-25. Degenerative action can be obtained in other ways. Regardless of the means chosen to acquire negative feedback, the effect is the same; frequency response is extended.



A SHUNT PEAKING A-C CIRCUIT

B SERIES PEAKING A-C CIRCUIT



C EFFECT OF PEAKING CIRCUITS ON BANDWIDTH

Figure 54. High-frequency compensation.

11-26. We need mention here that for an r-f carrier system, r-f and i-f amplifiers must have an overall bandwidth which is broad enough to pass all the video information. The bandwidth of tuned amplifiers is broadened by: (1) lowering the Q of the tank circuits, (2) close coupling, and (3) stagger tuning. By one or a combination of these ways, the required band of frequencies can be developed for detection and subsequent video amplification.

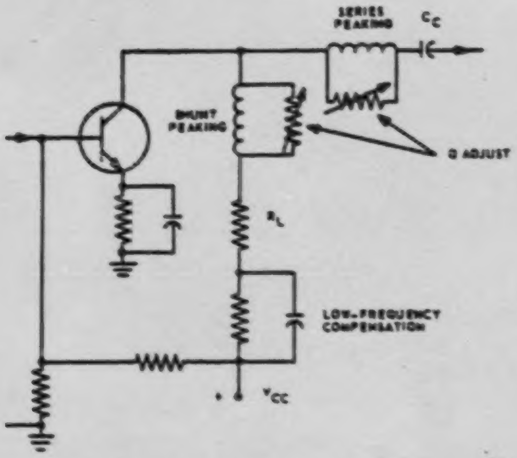


Figure 55. Video amplifier with compensation circuits.

11-27. *Comparison of transistor and tube video amplifiers.* Although a high gain (about 40 db) can be obtained from a single transistor amplifier, input and output impedance requirements limit the gain to much lower values. Ordinarily it takes two transistor stages to obtain a gain comparable to a single pentode tube amplifier. Even so, the power supply requirements and space occupied by transistor amplifiers are considerably less than those of tube amplifiers.

11-28. Good quality transistors with high-frequency cutoff values (20 mc and better) are plentiful nowadays. Therefore, attaining the high-frequency response needed for a video signal poses no serious problem. In fact, with low-gain per stage, the high-frequency response may be quite adequate for excellent performance. Considering the adaptability of transistors to direct coupling, it is not surprising to find this

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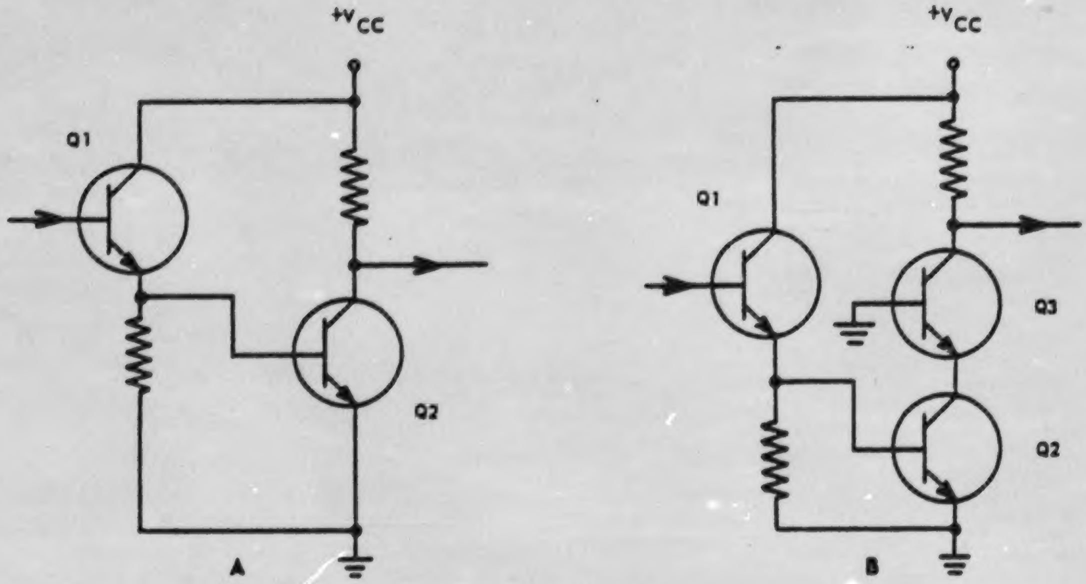


Figure 56. Transistor video amplifiers.

coupling used extensively to insure low-frequency response and d-c transfer. The use of direct coupling and low-gain amplification makes compensating circuits unnecessary in many cases. Although we showed that a transistor video amplifier circuit may incorporate compensating circuits, you should realize that some do not. Figure 56 shows two such circuits which are commonplace. Note the simplicity of these arrangements. You should recognize these configurations and know why video amplification is attainable without compensating circuitry.

CHAPTER 5

Monitoring Facilities

MONITORING facilities and the number of video display equipments depend largely upon the size and complexity of a system. As a maintenance man, you are well aware of the importance of monitors. Undoubtedly, much of your troubleshooting and repair has directly or indirectly involved various types of monitors. Regardless of the type or configuration, monitors have certain essential sections. In this chapter we will identify these sections and discuss, in a comparative manner, the viewfinder, utility, and combination (camera control or master) monitors. As before, we have chosen to analyze transistor circuitry. By so doing, we can further your transistor training while discussing the operating principles of monitor equipment. Test-points and waveforms relevant to adjustments, alignment, and tuning are also discussed. Using a block diagram of a master monitor, we will diagnose troubles from known symptoms.

12. Monitors

12-1. Technical personnel rely upon monitors to check the condition of the television picture and video waveform being transmitted; therefore, both picture monitors and waveform monitors are needed. Picture monitors use direct-view display kinescopes and contain many of the essential sections found in TV receivers. Many of the principles covered in this chapter will be fully applicable to our study of receivers in the following volume. Since monitors reproduce a picture from a video-frequency signal, the signal is generally taken directly from a video line. However, in an extensive closed-circuit system, provision is made for monitors to take the demodulated output of a receiver. For r-f distribution, the receiver's r-f and i-f sections are necessary to obtain the video-frequency signal for the monitor. The picture monitor is used in this manner because it is designed to have a broader bandpass and better gray-scale reproduction characteristics than the video section of a comparable receiver. In other words, the receiver-monitor combination gives a higher quality picture than a receiver designed for ordinary viewing. We mention this to point up the qualitative superiority of picture monitors.

12-2. The combination of waveform monitor and picture monitor is used in conjunction with the camera control unit studied in the preceding chapter. The waveform monitor displays the video signal on a CRT so that the waveform can be checked against the signal standards of the system. A combination monitor, picture and waveform, is also used as a master monitor to display the picture and video signal being transmitted. More will be said about master monitors after we have considered picture and waveform monitors separately.

12-3. **Essential Sections.** Figure 57 shows the block diagram of a picture monitor. The composite video signal is fed into the video section, which consists of video amplifiers and a d-c restorer. This section contains sufficient amplifying stages to develop the output signal strength required. Note that there are two outputs taken from the video section of this monitor. One output signal is obtained from the d-c restorer circuit and sent to the cathode or grid of the kinescope. This signal, which contains all the picture information, effectively modulates the intensity of the kinescope's electron beam. The other signal that is coupled into the sync section is used to obtain timing pulses for the vertical and horizontal section. We should mention here that the sync section is not essential to all monitors. For example, recall that the viewfinder monitor uses the camera's output signal, which does not contain any sync pulse. This type monitor will most likely have separate inputs of horizontal and vertical drive for timing the horizontal and vertical sections, respectively. In our block diagram we have indicated a switch S. Many picture monitors provide such a switch so that either sync pulses (from the sync section) or drive

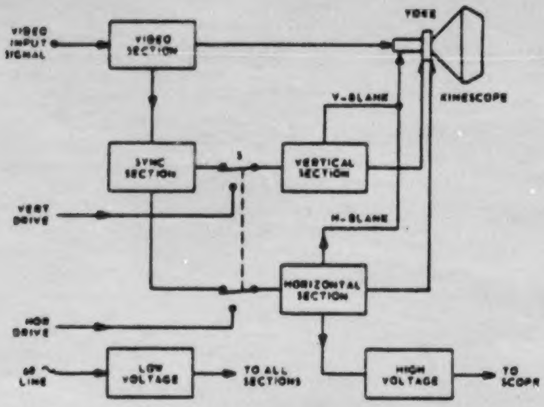


Figure 57. Sections of a picture monitor.

pulses (from separate inputs) may be selected for timing purposes. The vertical section, of course, generates and shapes the signal that is sent to the yoke's deflection coil for vertically scanning the kinescope's screen. Usually, a vertical blank signal is also obtained from this section and applied to the kinescope's grid or cathode to insure beam cutoff during vertical flyback. The horizontal section develops signals for horizontal scanning and blanking. In addition, this section provides the excitation signal for the high-voltage d-c supply. Low voltage is developed from the 60-cps line input as shown.

12-4. Look now at figure 58 and observe that the waveform monitor's block diagram differs from that of a picture monitor (fig. 42). You should recognize the waveform monitor to be a cathode-ray oscilloscope (CRO). It employs a cathode-ray tube (CRT) and uses electrostatic deflection. The signal to be observed is applied to the electrodes of the CRT after being amplified by the video section. Switch S1 permits selection of a calibrating signal so that time and amplitude measurements can be read from the scope presentation. A square-wave signal of known amplitude and period is supplied by the calibrating section. The displayed calibrating signal is readily adjusted to markings on the scope's face. Therefore, when the composite video signal is selected by S1, pulse widths and voltage values can be determined. Remember, however, that the scope's gain controls should not be disturbed once they have been adjusted to give a calibrated reading. Testing with a waveform monitor is just like using a high-quality CRO that has calibrating capabilities. The sweep section is similar also, but is designed to sweep at a submultiple of the picture signal field or line rate. In a standard system, it ordinarily sweeps at one-half the field or line rate; thus 30 cps or 7875 cps, respectively. This one-half field or line rate permits viewing two complete periods of the vertical or horizontal video waveforms. There are other features unique to this CRO, but we will not investigate them here. A detailed block diagram of a master monitor will reveal these features; therefore, we have reserved our discussion of them until later. Our purpose here is simply to identify the essential sections of the waveform monitor and have you compare this monitor with a picture monitor with regard to its basic makeup.

12-5. **Types of Monitors.** Although you have used and maintained many types of monitors, perhaps you have given little thought to why such a variety of circuits is found within them. Some of this variety is a matter of the designer's choice; however, the number of stages and refinements is mostly dictated by performance requirements for a particular type of monitor. By type we mean whether it is a viewfinder, utility (line), or combination (camera control or master) monitor. These types contain the essential sections discussed; however, the circuitry within the sections may differ considerably. This is mainly because each type serves a different monitoring purpose.

12-6. The viewfinder used with the image orthicon camera is a comparatively uncomplicated picture monitor. Its video section may have just two broadband amplifiers and a d-c restorer circuit. Its vertical section, which is triggered by input vertical drive pulses, will have a blocking oscillator or multivibrator, one or two driver stages, and an output amplifier. The same is true for the horizontal section, except of course that it is triggered by horizontal drive pulses and is designed for a much higher frequency. Some viewfinders have several stages to develop a composite blanking signal derived from the video input. These stages shape, amplify, and mix to produce the blanking pulses of the width and

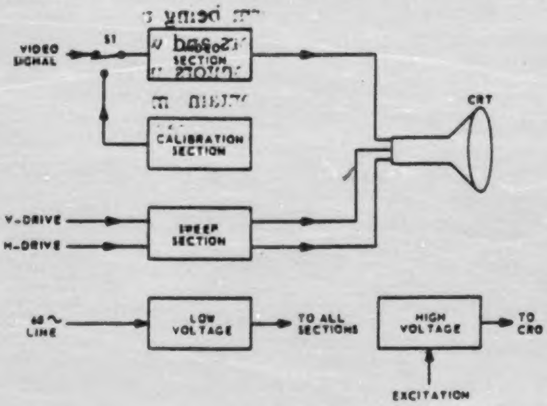


Figure 58. Sections of a waveform monitor.

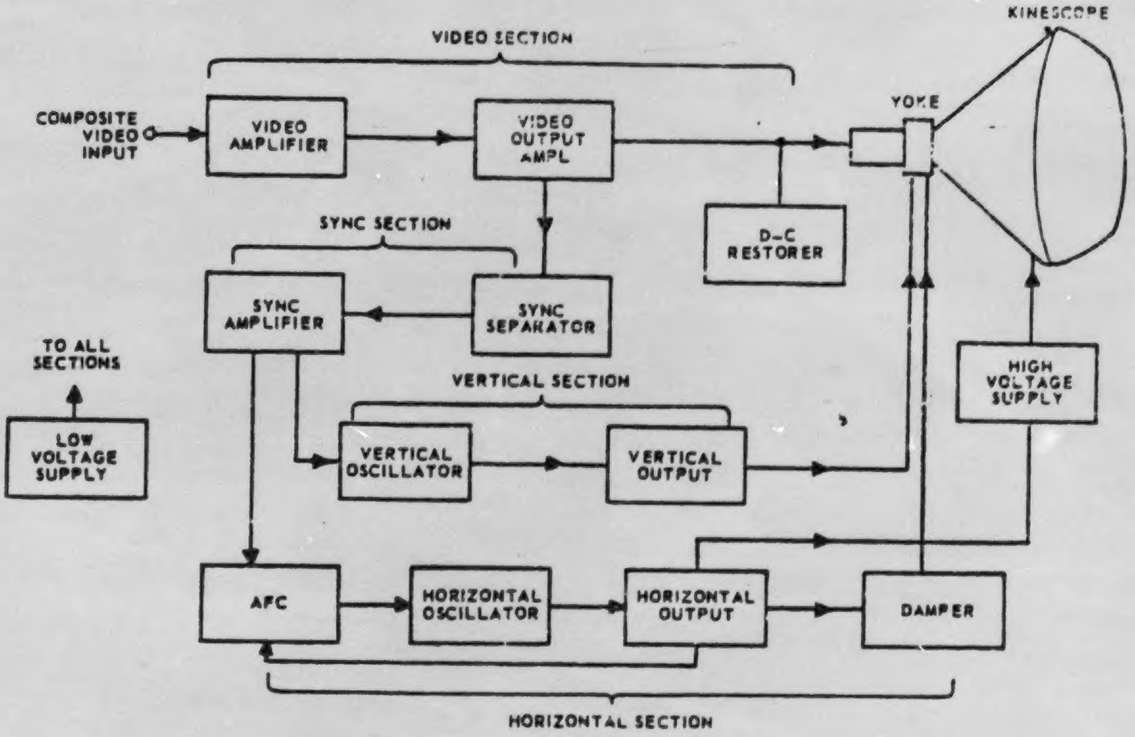

VIDEO SECTION
KINESCOPE
COMPOSITE VIDEO INPUT
VIDEO AMPLIFIER
VIDEO OUTPUT AMPL
YOKE
D-C RESTORER
SYNC SECTION
SYNC AMPLIFIER
SYNC SEPARATOR
TO ALL SECTIONS
LOW VOLTAGE SUPPLY
VERTICAL SECTION
VERTICAL OSCILLATOR
VERTICAL OUTPUT
HIGH VOLTAGE SUPPLY
AFC
HORIZONTAL OSCILLATOR
HORIZONTAL OUTPUT
DAMPER
HORIZONTAL SECTION

Figure 59. Block diagram of stages within a utility monitor.

amplitude desired. Since a small-screen (4 to 6 inches) kinescope is used, the requirements for good picture resolution are not difficult to meet. The viewfinder's primary purpose is to orient the camera for video pickup, so it need not display the high-quality picture that must be displayed for evaluation, control, or detailed viewing.

12-7. Utility monitors are employed mostly for viewing the televised scene at various locations throughout a system. They are placed within the studio for previewing and line monitoring. In a closed-circuit system, they are commonly used as the terminal display equipment for general viewing. The size of the kinescope is determined by the particular application. In classrooms and offices, 24-inch tubes are generally satisfactory. In a studio, 17-inch or 8-inch tubes are adequate for continuity checks or cueing work. Depending upon tube size and resolution necessary, utility monitors may have few or many stages per section. Moreover, you will find many refinements or basic circuits which improve the overall picture quality.

12-8. Figure 59 shows a block diagram of a utility monitor that contains the minimum number of stages practical. We will investigate the circuitry of each of these stages shortly. For now, it is sufficient that you recognize what stages constitute a utility monitor. Unlike the viewfinder, this monitor obtains its sync from the composite video input. A sync separator is therefore an integral part of a utility monitor. Note also that the horizontal oscillator is indirectly controlled by the horizontal sync pulses which are used for afc.

12-9. A combination picture and waveform monitor is always associated with the camera control unit. When this combination is connected across the outgoing circuit, it is called a master monitor. The master monitor visually displays the results of all mixing, switching, gain adjustment, and other signal manipulations. As pointed out earlier, the waveform monitor has built-in calibration facilities for measurement purposes. Because this type of monitor is designed for picture and signal analysis, it must meet high-quality performance specifications. Consequently, it contains a greater number of stages and more sophisticated circuitry than either the viewfinder or utility monitor.

12-10. **Transistor Circuits.** Practical transistor circuits are connected in figure 60 to make up a monitor schematic. To stress their operational features and pertinent components, only the nec-

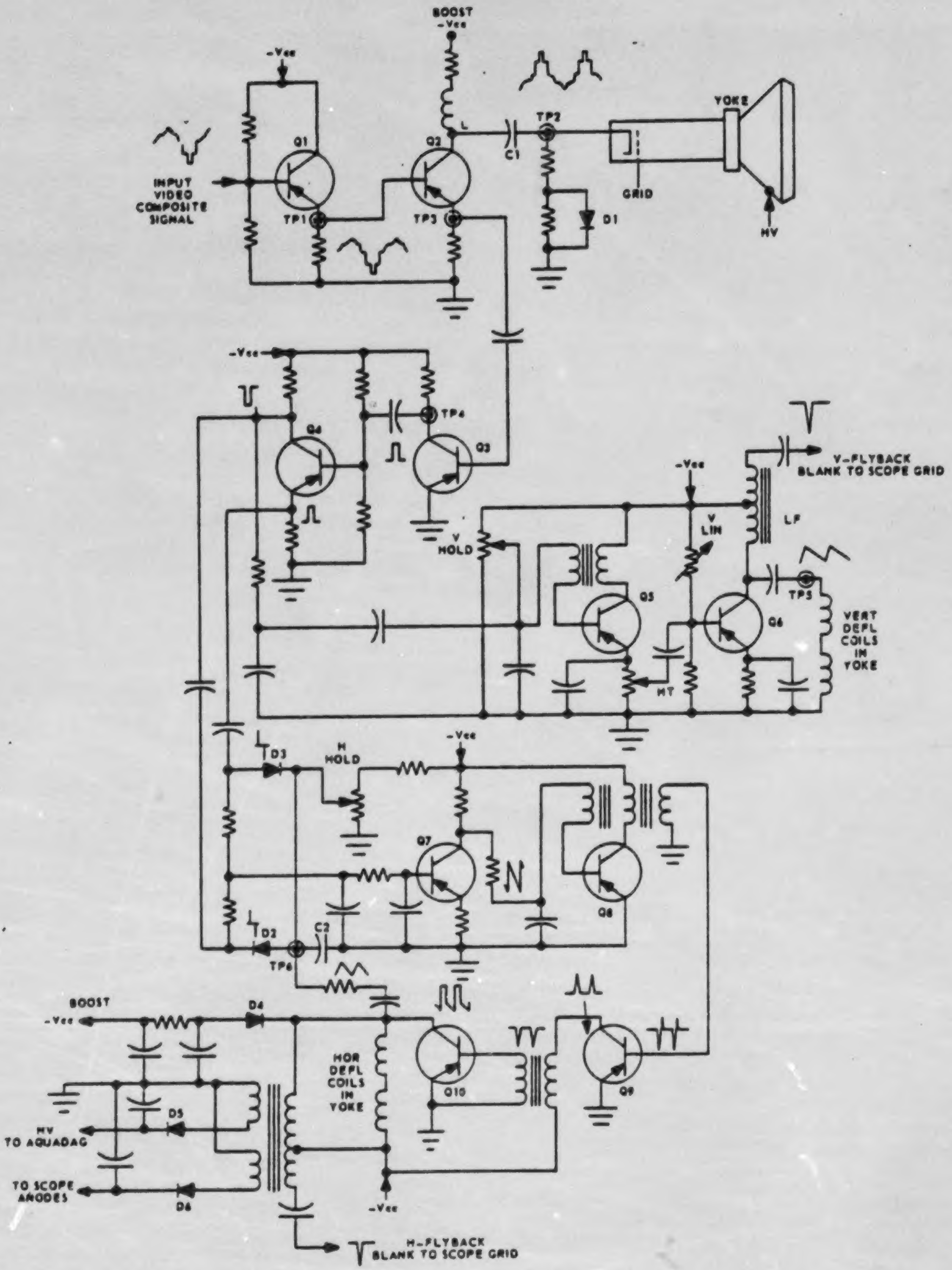

BOOST
-Vcc
-Vcc
Q1
Q2
L
C1
TP2
YOKE
INPUT
VIDEO
COMPOSITE
SIGNAL
TP1
TP3
GRID
D1
HV
-Vcc
TP4
Q4
Q3
V-FLYBACK
BLANK TO SCOPE GRID
-Vcc
V
HOLD
V
LIN
LF
Q5
Q6
TP5
VERT
DEFL
COILS
IN
YOKE
HT
D3
H
HOLD
-Vcc
Q7
Q8
D2
C2
TP6
BOOST
-Vcc
D4
HOR
DEFL
COILS
IN
YOKE
Q10
Q9
HV
TO AQUADAG
D5
TO SCOPE
ANODES
D6
-Vcc
H-FLYBACK
BLANK TO SCOPE GRID

Figure 60. Schematic of transistorized picture monitor.

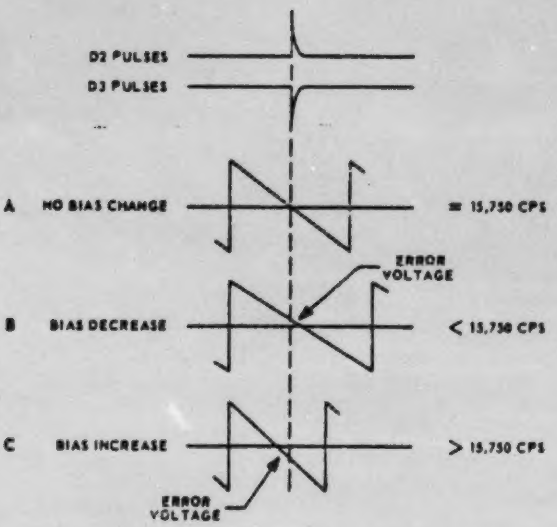


Figure 61. Waveforms illustrating the presence of an error for afc.

essary circuits are shown. Special circuits found in manufacturers' schematics are too numerous and varied to include. Our treatment is necessarily limited, but will be valuable to you insofar as you understand the functions of each stage and their relationship to each other. The most common transistor configurations have been selected. To acquaint you more with p-n-p transistor biasing and interconnections, we chose to use this type transistor throughout. Bear in mind, however, that n-p-n transistors can be used as well, but the d-c bias voltages must be positive. Regardless of the transistor type (p-n-p or n-p-n), waveforms and circuit functions are the same. As we progress through this schematic, note how similar these stages are to comparable tube stages which you have studied.

12-11. *Video section.* Any of the three transistor configurations can be used for the input video amplifier. In figure 60 we show a common-collector (CC) video input stage because this configuration is most popular. Recall that the CC arrangement presents a higher input impedance and minimizes distortion caused by collector-base capacitive feedback. Generally a high input impedance is desirable, which explains the choice of the CC amplifier. At testpoint TP1 (fig. 60), you see that the composite video signal is identical to the input in phase and waveform. There is no need for compensating circuits since the emitter-follower action of Q1 gives the necessary broadband response to faithfully reproduce the input video. Direct coupling to transistor Q2 insures maximum low-frequency transfer and also biases the base of Q2.

12-12. The video output stage shown has two outputs which are seen at TP2 and TP3. At TP2 the signal is inverted with respect to the input because it is taken off the collector of Q2. This signal goes to the cathode of the kinescope. Cathode drive is frequently preferred, since it requires about 20 percent less signal voltage than grid drive for the same beam modulation. To obtain the necessary driving power, transistor Q2 is supplied a high collector bias from the boost supply (damper circuit of horizontal section). The desired broadband response is attained with shunt peaking (coil L) and the unbypassed emitter resistor. This resistor also serves to counteract bias variations caused by temperature. Moreover, it develops the video signal (seen at TP3) which is needed for the sync section.

12-13. D-c restoration is accomplished by the clamping action of diode D1 in conjunction with the coupling capacitor C1. The waveform illustrated at TP2 shows that the video signal is clamped to the peaks of the sync pulses.

12-14. *Sync section.* The signal at TP3 should have the same waveform as shown at TP1. This signal is capacitively coupled into the sync separator stage via the base of Q3. The coupling capacitor is of such a value that the transistor Q3 is self-biased to amplify only the sync pulses. In other words, the transistor biases itself below cutoff; only the most negative portion of the input composite signal drives Q3 into conduction. Thus, the sync signal appears as positive-going pulses at TP4.

12-15. The separated sync signal is capacitively coupled to the base of Q4. Transistor Q4 and its associated circuitry comprise a phase-splitter amplifier (also called a phase inverter). As illustrated in figure 60, sync signals of equal amplitude but opposite phase are present at the collector and emitter of Q4. This stage uses fixed bias to properly amplify and clip the signal.

12-16. *Vertical section.* The vertical section consists of a vertical oscillator and an output amplifier containing transistors Q5 and Q6, respectively. From the block diagram (fig. 59), recall that this section receives its timing pulses from the sync section. We see on the schematic in figure 60 that negative-going sync pulses from the collector of Q4 are applied across an RC integrating circuit. The resistor in series with the input capacitance to the blocking oscillator is a long-time constant circuit for the horizontal sync pulses. Consequently, only the vertical sync pulses are developed to trigger Q5. You should recognize the blocking oscillator arrangement incorporating Q5. The free-running frequency of this oscillator is adjusted to be slightly less than the vertical sync frequency. This is readily done by changing Q5's base bias with the V-hold control (see fig. 60). The blocking oscillator is used because it shows less variation with temperature than a transistorized multivibrator. Besides having better stability, the blocking oscillator has fewer components. Although a blocking oscillator ordinarily generates a pulse, a sawtooth waveform can be achieved by connecting a capacitor of the proper value across the output; in this case, the capacitor is across the emitter resistor. The amplitude of the signal coupled to the vertical output amplifier is adjustable. This is accomplished with the height control (labeled "Ht" on the schematic).

12-17. Note that the bias on the base of Q6 can be varied. This adjusts the vertical linearity by changing the operating point of the transistor. The control is labeled "V-Lin" on the schematic and is used in conjunction with the height control to obtain a properly proportioned vertical display on the scope screen. As you know from experience, both of these controls must be adjusted to produce a linear vertical scan of correct amplitude. The function of the vertical output amplifier is to drive the vertical deflection coils. Unlike the tube version of this stage, a transformer is not necessary for matching. The output impedance of the transistor circuit is low enough to match the impedance of the vertical deflection coils. Thus, the output is shown to be capacitively coupled directly to the vertical deflection coils in the yoke. At the low field frequency (60 cps), the impedance of these coils is mostly resistive; so a sawtooth waveform is seen at TP5. The amplitude of the sawtooth current depends upon the kinescope used—about 500 ma peak to peak is typical. This means that a power transistor is needed since better than 1 watt of power is ordinarily required. Efficiency of this stage is necessarily low, because it must operate class A for linear amplification. As in tube applications, class AB or B push-pull operation may be used when higher efficiency at greater power levels is required.

12-18. A vertical blanking signal is shown developed off the end of the tapped L.F. choke that serves as a collector load impedance. Note that negative-going pulses are sent to the grid of the kinescope. This insures beam cutoff during vertical retrace. There are other ways to achieve effective vertical blanking. For example, positive-going pulses can be developed off the collector and applied to the kinescope's cathode.

12-19. *Horizontal section.* Let us quickly investigate the schematic to identify the stages in the horizontal section. The circuits that include D2, D3, and Q7 constitute the afc for holding the horizontal oscillator on frequency. Transistor Q8 and its associated components are easily seen to be a blocking oscillator which feeds pulses to the base of Q9. The pulses are amplified by the driver stage consisting of Q9 and a pulse transformer. The next stage, of course, is the horizontal output amplifier. From this final stage, power must be developed to supply outputs to the HV supplies, boost supply, afc input, horizontal blanking circuit, and horizontal deflecting coils.

12-20. The inputs to the horizontal section are taken from the phase-splitter. Off the collector of Q4, negative-going sync pulses are applied across a short-time constant RC (differentiating) circuit. Therefore, negative- and positive-going spikes appear at the cathode of diode D2, as shown. In like manner, positive-going sync pulses (off the emitter of Q4) are changed into positive- and negative-going spikes at the anode of diode D3. At the same instant that D3 conducts a positive-going spike, D2 conducts a negative-going spike of equal amplitude. Being of opposite polarity, they cancel and therefore do not affect the base bias of Q7. However, if the sawtooth signal coupled into TP6 is not exactly midway between peaks at the instant D2 and D3 conduct (see fig. 61), an error voltage changes the base bias of Q7. This change is amplified and applied to the base of Q8, accordingly, the frequency of the blocking oscillator is controlled.

12-21. Our brief description of the phase detector and d-c amplifier for afc should be adequate for you to note that afc principles are the same as for tubes. Solid-state versions of other afc arrangements do not differ appreciably from those you have previously encountered.

12-22. On the schematic in figure 60, the base bias of Q7 is shown to be adjustable with the H-hold control. This adjustment indirectly establishes the free-running frequency of the horizontal oscillator by setting the base bias of Q8. Transistor Q8 should be biased so that the afc operates over its maximum designed range of control. Unlike the vertical oscillator, the horizontal oscillator is designed to give a pulse output. The circuit illustrated uses a three-winding transformer. The pulses generated by the blocking oscillator are inductively coupled to the transformer's tertiary winding. This winding inverts the pulses from the collector circuit; thus, a strong negative pulse is fed to the base of Q9. The positive overshoot, if there is one, does not affect Q9 since Q9 is biased at cutoff (both base and emitter are at d-c ground).

12-23. Transistor Q9 is connected as a class B, CE amplifier. It serves to develop sufficient drive for the horizontal output stage. The positive-going pulses developed at its collector appear as negative pulses at the base of Q10 due to the action of the coupling transformer. Because of the inversion that occurs from base to collector, the pulses seen across the load impedance (collector to ground) are positive-going as illustrated. As in a comparable tube horizontal output stage, the shape of the output waveform must be such that it produces a sawtooth current through the deflection coils. This same waveform is fed back to the phase detector via a long time constant RC circuit. The voltage developed across C2 is therefore a sawtooth signal which is seen at TP6.

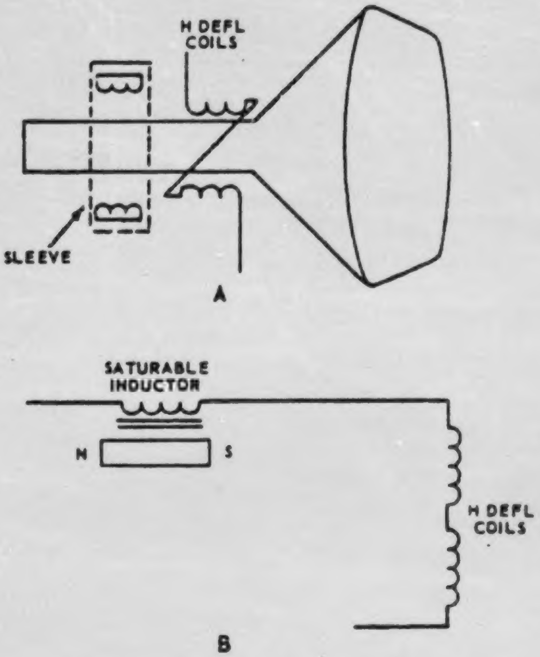
12-24. Boost and high-voltage rectifying circuits receive their excitation from the horizontal output stage. Note that the negative d-c boost voltage is developed by the damping diode D4. The circuits containing D5 and D6 are half-wave rectifiers that develop the positive d-c voltages needed for the kinescope.

12-25. Although we have shown no provision to adjust the width of the horizontal scan, there are several ways to do this. A common way is to insert a variable ferrite-core inductor in series with the deflection coils. Another way is to use a horizontal output transformer that has a variable air gap. It is also possible to provide a variable bias which alters the gain of the output amplifier. Such width controls practically always affect the high-voltage afc feedback and blanking circuits. For this reason, monitors may not have a width control; instead, their horizontal output circuit is designed to overscan slightly. Sometimes a shorted-turns linearity sleeving is used to adjust both horizontal linearity and picture width (see fig. 62,A). The sleeve around the neck of the kinescope changes the picture width when it is moved forward or backward. It can also be adjusted to improve linearity of the horizontal scan. Another method to adjust linearity (see fig. 62,B) employs a permanent bar magnet and saturable inductor in series with the deflection coils. Depending upon the closeness of the magnet, magnetic saturation occurs and thereby alters the scanning waveform. When properly adjusted, a linear scan is obtained.

12-26. *Kinescope.* The kinescope in a transistor monitor is essentially the same as that in a tube set, but it usually has a smaller screen diameter and beam deflection angle. Most transistor monitors use 90°, 8–14 inch, aluminized rectangular picture tubes, because transistor monitors have tended to be battery- or low-power sets. Larger screens and wider deflection angles are not economically practical for such sets. Aluminized screens are commonplace, since they produce good brightness at comparatively low beam currents, average values of 75 to 150 μa for transistor monitors.

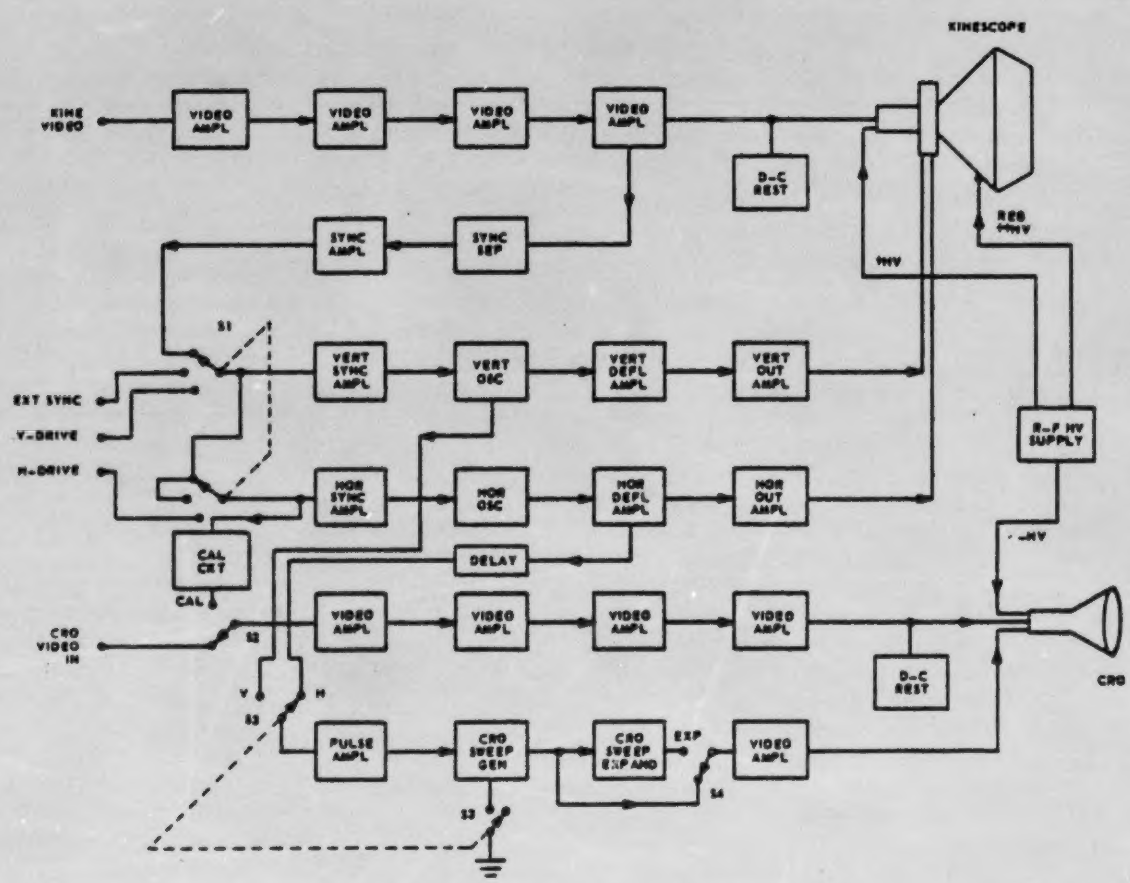
12-27. Present-day kinescopes have from five to seven electrodes. These electrodes are used in various ways to electrostatically control picture brightness and focus. The cathode-to-grid potential is made variable over a range of several tens of volts so that the intensity of the beam, and thus picture brightness, can be adjusted. From a potentiometer, 100 to 300 positive d-c volts is applied to the first anode. Sometimes in a pentode kinescope, the first and second anode are connected to provide a focus control. Electrostatic focus control is being used extensively. Ordinarily, you control the focus by adjusting the potential on one of the accelerating anodes.

12-28. In addition to electrostatic controls, there are magnetic adjustments that are important. No doubt you have found that these adjustments differ somewhat because of manufacturing differences. Electromagnet controls have been replaced for the most part by permanent magnet adjustments. External magnets, mounted about the kinescope, are used in transistor and tube monitors to serve several purposes, such as preventing ion burns, focusing, centering, and picture correction. Ion-trap magnets are not needed for aluminized screens but are used for other types. A clamp secures the ion-trap magnet around the neck. By design,



A. SHORT-TURNS SLEEVE B. SATURABLE INDUCTOR

Figure 62. Methods of adjusting horizontal linearity.


KINESCOPE
KINE VIDEO
VIDEO AMPL
VIDEO AMPL
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VIDEO AMPL
D-C REST
REG +HV
SYNC AMPL
SYNC SEP
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S1
VERT SYNC AMPL
VERT OSC
VERT DEFL AMPL
VERT OUT AMPL
EXT SYNC
V-DRIVE
H-DRIVE
R-F HV SUPPLY
HOR SYNC AMPL
HOR OSC
HOR DEFL AMPL
HOR OUT AMPL
CAL CKT
-HV
DELAY
CAL
CRO VIDEO IN
S2
VIDEO AMPL
VIDEO AMPL
VIDEO AMPL
VIDEO AMPL
D-C REST
CRO
V
H
S3
PULSE AMPL
CRO SWEEP GEN
CRO SWEEP EXPAND
EXP
VIDEO AMPL
S4
S3

Figure 63. Combination monitor block diagram.

the electron gun is aimed into the neck wall. When the ion-trap magnet is properly adjusted, the electrons are redirected along the beam axis, but the heavier ions are not. The ions strike an anode, and the screen is protected from their bombardment and the burning damage that results. A focusing magnet is sometimes used instead of or in conjunction with electrostatic focusing. A magnet, called a beam-centering magnet, is also fitted around the neck of a kinescope for steering the beam so that it is centered within the final anode aperture. In addition, a picture-centering magnet, which is usually adjustable with a lever or knob, positions the picture properly on the screen. Lastly, a magnet is fitted against the flare of the tube to correct for geometric distortions and eliminate corner shadowing. Beginning at the tube base, you will ordinarily find these magnets mounted in the following order: ion-trap, focusing, beam centering, picture centering, and picture correction.

13. Master Monitor

13-1. Earlier we briefly discussed the combination monitor, and pointed out that it is used to maintain a constant check on the picture quality and signal waveform. It can be connected to a switching arrangement so that the transmitted information or any of several cameras can be monitored. When used in this manner, it is correctly called a master monitor. However, this name is also applied to a combination picture and waveform monitor assembled in a single console or field case. In this section we will consider how such an assembly may be made. By investigating a block diagram, we will show how the picture and waveform monitors can be interconnected. Because of the interdependency of some stages, certain symptoms are readily related to specific troubles. Therefore, we will diagnose troubles after analyzing the block diagram.

13-2. **Functional Analysis.** The block diagram in figure 63 illustrates the relationships of the various stages and circuits that comprise a master monitor. Moreover, this diagram shows how switches provide versatility and commonize certain stages so that they serve both the picture and waveform sections. Although this type monitor is more complex than either the picture or waveform monitor taken singularly, you will note, as we progress, that it is quite simple in some respects.

13-3. *Picture sections.* Beginning at the upper left of the block diagram, observe that the kinescope signal goes through four stages of video amplification. The video amplifiers are designed to have excellent response for a wide video band (about 8 mc). To achieve such high-quality performance, the gain of each stage is comparatively low. This explains why it is generally necessary to use numerous stages to develop the signal drive for the kinescope. The d-c restorer is shown as a separate circuit, but may in some sets be an integral part of the last video stage. Sometimes d-c restoration is associated with sync separation so that it may be represented differently in the block diagram of a particular set. The composite video signal for sync separation is usually obtained from the last video amplifier. Depending upon the gain of the sync separator, the separated sync is coupled to an amplifier, as indicated in figure 63. This amplifier may not be round in some sets.

13-4. With switch S1 in the position illustrated, the separated sync signal goes to both the vertical and horizontal sync amplifiers. The input circuit of the vertical amplifier integrates the signal; therefore, only the vertical sync pulses are developed. These pulses become amplified and trigger the vertical oscillator. Observe that there are two outputs from the vertical oscillator, one goes to switch S3 (which will be discussed shortly) and the other goes to the vertical deflection amplifier which serves as a buffer and driver stage. Since the vertical output amplifier is often a push-pull circuit, it may be represented by two blocks. Regardless, its function is the same; namely, to produce a linear sawtooth with adequate power for full vertical deflection of the kinescope's beam.

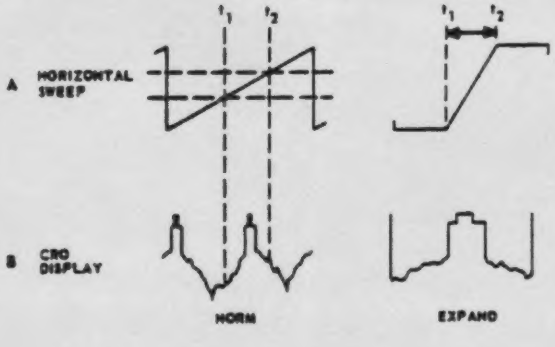


Figure 64. Effects of sweep expand.

13-5. Returning to switch S1 and noting the signal path through the horizontal section, you find stages corresponding to those just described in the vertical section. You know, however, that the input circuit to the horizontal sync amplifier must differentiate the sync signal to obtain only the horizontal sync information. Then the horizontal sync pulses are amplified to trigger the horizontal oscillator. You may ask, "Why isn't afc used?" Unlike many picture monitors, which may be connected almost anywhere in the system, a master monitor is connected at the transmitting end. Its video input is therefore far less subject to noise. Because of the high signal-to-noise ratio, the horizontal sync pulses can be used to reliably trigger the horizontal oscillator. This gives better control and dispenses with the extra circuitry for indirect control by afc. In this respect, at least, the master monitor is simpler. The other horizontal stages are similar to those of a picture monitor, but for a master monitor their outputs are somewhat different. In addition to driving the output amplifier, the horizontal deflection amplifier sends an output via a delay line (or delay multivibrator) to switch S3. Therefore, it serves the waveform monitor also. The horizontal output amplifier has but one output indicated. It does not provide an output to the high-voltage power supply. The d-c high-voltage for the kinescope of this type monitor has stringent requirements which are best met by a separate high-voltage power supply unit. This type power supply was studied in Chapter 2, Section 6 (see fig. 27).

13-6. Up to this point, switch S1 has been considered set at the position shown in figure 63. It is worthy to note that by means of this switch, separated-sync, external-sync, or drive signals can be selected as inputs to the horizontal and vertical sections. Study the diagram to see how this is done. External sync is generally preferred when the monitor is used as a switching or line monitor, whereas drive inputs are used for monitoring camera equipments.

13-7. *Waveform CRO.* The input to the CRO's video section is selected by switch S2. When S2 is in the position shown, the video signal waveform is displayed on the CRO's screen. This signal may be obtained from a common video signal source if the CRO input and KINE input terminals are connected together. Thus, separate input terminals enable the operator to observe the same or different video signals on the kinescope and CRO. When

S2 is switched to the CAL position, a square-wave signal of known amplitude is displayed on the CRO's screen. As explained earlier, such a signal makes it possible to calibrate the CRO and thus make direct measurement readings of an observed waveform. Note that the calibration circuit (CAL CKT block in fig. 63) obtains its input as S1. No matter what position S1 is in, horizontal pulses (separated sync, external sync, or H-drive) are applied to the calibration circuit. This circuit is generally nothing more than a clipper network that clips the pulses at a prescribed known upper and lower limit.

13-8. Like the video section of the kinescope, and for the same reason, four stages of video amplification are provided. We also see d-c restoration employed. The processed video signal is applied to the vertical deflecting plates (not shown) of the CRT. Bear in mind that we are now dealing with electrostatic deflection. When a sawtooth of proper frequency is applied to the horizontal deflecting plates of the CRT, the video signal waveform is displayed. Let us give our attention therefore to the means by which the sawtooth signal is obtained for horizontal deflection.

13-9. Switch S3 is marked V (vertical) and H (horizontal). In the H position, pulses from the horizontal deflection amplifier are sent through a variable delay circuit to the input of the pulse amplifier. The output of this amplifier synchronizes the CRO sweep generator so that the sawtooth signal produced has one-half the frequency of the horizontal oscillator (the source of the pulses). If the horizontal oscillator frequency is 15,750 cps, then the CRO sawtooth frequency is 7,875 cps. Since the latter is the horizontal sweep frequency, two cycles of the horizontal video waveform are displayed on the CRT's screen. The variable delay circuit makes it possible to delay the start time of the horizontal sweep in order to observe two complete horizontal blank and sync pulses in the video waveform. To examine vertical pulses, S3 is set in the V position. When this is done, the dashed line in the diagram shows that a switch at the CRO sweep generator is closed to ground. This increases the time constant and decreases the free-running frequency of the sweep generator to a value slightly less than one-half the vertical oscillator frequency. When synchronized, the sweep frequency is exactly 30 cps for a 60-cps vertical rate. Consequently, two cycles of the vertical video waveform are displayed on the CRT's screen.

13-10. The sweep-expand stage permits an operator to expand a portion of the waveform and thereby carefully scrutinize it. Figure 64 shows the effect of this stage when switch S4 of figure 63 is used. Note how the horizontal sweep waveform is modified when S4 is set at EXP. The output from the CRO sweep expand is of the same amplitude, but only the center portion produces a sweep. That portion of the waveform, in time interval t_1 to t_2, is spread across the full width of the scope screen as illustrated. In other words, this portion of the waveform is expanded since full horizontal deflection occurs in a shorter time interval. The modified sweep that effects the expansion is formed by clipping the normal sawtooth (see fig. 64,A), then amplifying the clipped waveform to the same amplitude as the normal horizontal sweep signal.

13-11. An additional feature provided on master monitors is a switch to select pulse-cross display. We have not shown this switch in figure 63 since it would complicate the diagram. A short explanation should suffice for you to realize what this switch does. When it is set to PULSE CROSS position, the video signal is sent to the CRT's cathode or control grid, the expand-horizontal sweep signal is applied to the horizontal deflecting plates, and the expand-vertical sweep is applied to the vertical deflecting plates. The video signal intensity modulates the beam as it scans horizontally and vertically. You are familiar with the pulse-cross display pattern. Since this pattern is used as a convenient means of checking blank, sync, and drive pulses, it will be discussed with test patterns in the next volume. It is adequate here for you to appreciate how a pulse-cross pattern can be obtained by a switching arrangement.

13-12. **Trouble Diagnosis.** To logically determine the source of a trouble from a CRO or picture display, you must call upon your knowledge of monitor circuits and their functions. To illustrate this fact, and to give you some practice, let's diagnose some different types of troubles from symptoms that can be observed on a master monitor.

13-13. *Negative picture display.* When a picture appears like that shown in figure 65,A, you should know that the video signal is inverted. This means it has the opposite polarity to what it should have. Using a CRO, you can check the input video signal to see if it has the proper polarity. Referring to figure 63, note that the polarity can readily be checked with the waveform monitor. The amplitude of the input video should be checked also because too strong a signal can cause this symptom. An excessive input may overdrive one of the video amplifiers but still be coupled to the next stage. Such bypassing can cause the signal to have the wrong polarity

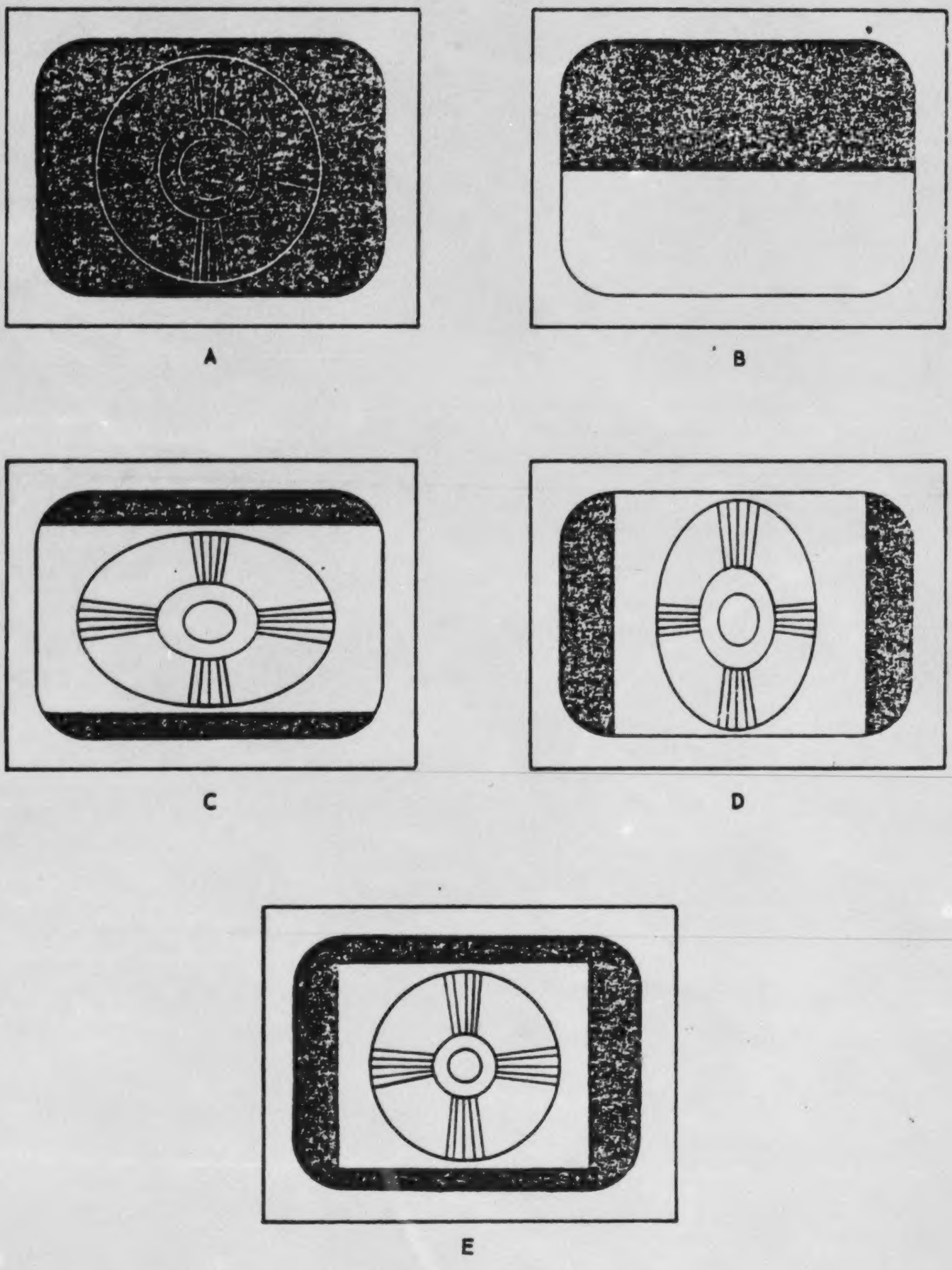


Figure 65. Abnormal displays.

when it reaches the kinescope. However, if you find the video input signal proper, you should use the CRO to signal trace the video section. A grid-to-plate (or base-to-collector) short can cause this trouble. The fault may also be a gassy tube.

13-14. *Half-black and half-white display.* The display illustrated in figure 65,B, could also appear white for the top half and black for the bottom half. In either case, you should know that this trouble is the result of a heater-to-cathode short. With a bit of thought, you will realize that the 60-cps heater voltage on the cathode cuts the beam off for half the raster and turns it on for the other half.

13-15. *Insufficient picture height.* If the condition illustrated in figure 65,C, cannot be corrected by adjusting the vertical height and linearity control, you should suspect the trouble to be in the vertical section. The vertical oscillator or vertical output stage should be checked.

13-16. *Insufficient picture width.* Too narrow a picture (fig. 65,D) which cannot be corrected by horizontal-width adjustment indicates trouble in the horizontal section. A weak tube (or transistor) in the horizontal oscillator, driver, or output stage will produce this symptom. A check of boost voltage and low-voltage d-c supply should be made, since inadequate d-c potentials will reduce the width of the horizontal scan.

13-17. *Insufficient height and width.* When the picture is small in size (fig. 65,E), the fault is usually in the low-voltage d-c supply. Of course, it can be the result of a combination of the two previous troubles described.

13-18. *Other abnormal displays.* Entire books are devoted to depicting abnormal displays and identifying these displays to specific troubles. Admittedly, we have but touched on the numerous picture symptoms that indicate trouble in a monitor. In your experience you have no doubt encountered the ones mentioned and many more, such as blooming, tearing, distorted patterns, keystoning, etc. As you apply the principles presented in this chapter, you will better understand the probable cause(s) of such displays.

CHAPTER 6

The Audio System

IT IS TRUE THAT some television applications, such as surveillance, require only the video system. However, in most television systems, audio is necessary to augment the video information, either as part of the program material or as intercommunications relative to the program production. In this chapter we will discuss microphones, audio amplifiers, and audio control consoles. Intercom systems will be discussed in the next volume.

2. The audio requirements for any given television system depend upon the function of the system. Just as a simple television system consists of one pickup camera and one monitor, so a simple audio system consists of one microphone, an amplifier, and one speaker. A moderate system will have several sound inputs; these will originate from the floor microphones and the announcer's or commentator's microphone. The various inputs are combined and sent out on a transmission line to one or several speaker setups. An additional monitor may be provided for control room use if necessary.

3. A television system which is intended for the presentation of more varied program material will demand a more complex audio system. Such a system would be one in which live-camera studios and a film studio furnish program material for distribution to classrooms. From the several microphones in the studios, the voice signals are fed to the audio control console in the control room. Other inputs to the control console come from the film studio and tape recorder. These signals are switched or mixed with the signals from the live studios and amplified to a controlled level. The output from the console then goes to the distribution network, with spare outputs available for patching to any other location where sound reproducing equipment is set up.

4. In addition to the output for the distribution network, the audio control console feeds the mixed program audio directly to the control room and also to a program monitor bus. A studio monitor speaker is patched off a muting relay; the speaker is thereby rendered inoperative to prevent acoustical feedback when studio microphones are operating.

5. From this discussion you can easily see the three major divisions of equipment used to produce an audio signal. A microphone, an amplifier, and a control console are used to convert an audio signal to electrical impulses, which are then amplified and fed to the console. Here, levels are set and the switching is accomplished.

14. Microphones

14-1. A microphone is a device which converts sound into an electrical signal, and applies this signal to an amplifying circuit. Following sufficient amplification, the electrical signal is used to drive a reproducer or to modulate a carrier frequency for transmission. The general characteristics of the most widely used types of microphones, dynamic, carbon, crystal, and capacitor will be discussed in this section. Each of these basic types of microphones employs a specific fundamental principle of operation.

14-2. The basic operation of a microphone is dependent upon pressure of sound waves. The angles at which the sound waves strike the diaphragm of a microphone depend upon the positioning of the microphone in relation to the sound source. If the sound waves strike the diaphragm at nonuniform angles, different frequencies will exert different pressures and cause the microphone to be directional in its frequency response. Most microphones are directional at frequencies above 2000 cps. Special construction of the microphone housing or case may produce additional directivity at frequencies below 2000 cps. Examples of specially constructed microphones are the "shotgun" and "reflector" types. Nondirectional microphones also require special design considerations. For nondirectivity it is necessary to design the housing so that signals from all directions exert uniform pressure on the diaphragm. The microphone which is de-

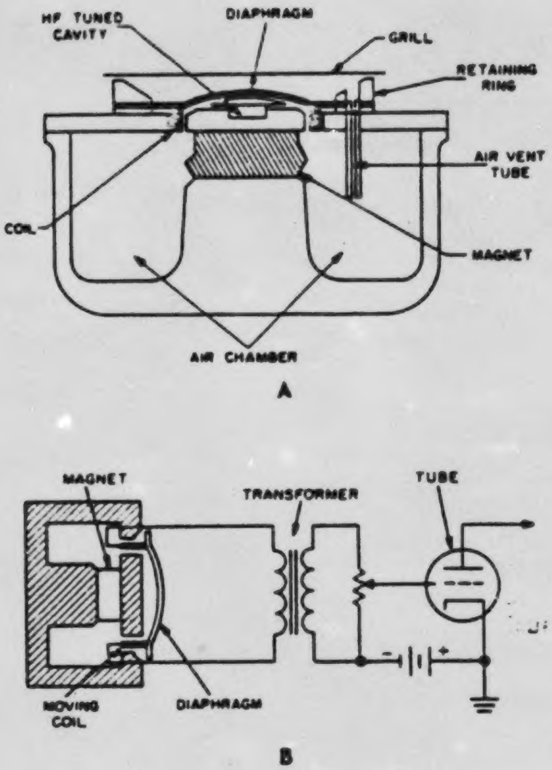


Figure 66. Dynamic microphone (A) mechanical details and (B) circuit diagram.

signed for general-purpose use is polydirectional; this type of microphone is usually mechanically adjustable to achieve the desired pattern of pickup.

14-3. **Dynamic.** The dynamic, or so-called moving-coil type, is the most widely used. Because of its low (and adjustable) impedance, it can be installed with long cables without serious adverse effect to the overall audio system; it is not easily damaged by rough handling and is not particularly sensitive to blasts (instantaneous sound peaks). A dynamic mike contains a coil made of a large number of turns of extremely thin metal ribbon attached to the diaphragm. This coil is insulated from the diaphragm by a thin coat of insulating varnish. The coil extends from the diaphragm to a point between the poles of a powerful permanent magnet. When sound waves strike the diaphragm, the coil moves back and forth within the magnetic field between the poles of the permanent magnet and cuts the magnetic lines of force. An illustration of a microphone designed to operate on this principle is shown in figure 66,A. This action induces a current in the coil in direct proportion to the sound pressure exerted on the disphragm.

14-4. The dynamic microphone elements are normally housed in a metal shell and covered with a metal grill and silk cloth to prevent damage from foreign particles and to minimize dust collection. The improvement in frequency response of this type of microphone over other types lies in the inclusion of an echo compensation circuit, which consists of an air chamber between the housing elements and an air-vent tube; the length and diameter of the air-vent tube control the echo-compensating action of the air chamber.

14-5. The impedance of the moving coil in the dynamic microphone is approximately 50 ohms; therefore, the coil may be connected to an amplifier by means of long cables. There are microphones available with built-in matching transformers to match low-Z of 30, 50, and 250 ohms or high-Z up to 50K ohms. A switch is built in to select the various impedances. The frequency response of this type of microphone is reasonably flat over the range from 40 cps to 10,000 cps. Since the output voltage level is only about 0.00004 volt, a preamplifier must be used for adequate amplification. The circuit diagram of the dynamic (moving coil) microphone is illustrated in figure 66,B.

14-6. The ribbon microphone, a variation of the dynamic microphone using the moving coil principle, is widely used in studio operations. It has no real diaphragm, and its operation depends upon the velocity of air. Therefore, it is sometimes called a velocity or pressure gradient microphone. The microphone, as shown by diagram in figure 67,A, consists of a powerful horseshoe-shaped electromagnet or permanent magnet, M, with special pole pieces between which a thin corrugated metal ribbon, R, is suspended. The ends of this ribbon are connected to the primary of a special step-up transformer.

14-7. The construction details of the ribbon microphone are illustrated in figure 67,B. The microphone should be placed so that the incoming sound will strike it at right angles, as those from the side have practically no effect. The sound striking the ribbon causes it to vibrate and thus cut some of the magnetic lines of force between the pole pieces. This action generates a voltage in the ribbon that is coupled to the grid of an amplifier via a special step-up transformer. Since the ribbon microphone is sensitive to velocity, it should be covered or otherwise shielded when used outdoors or in drafty areas, where air tends to produce undesirable ribbon vibrations.

14-8. The voltage output of the velocity microphone across 250 ohms is 0.0002 volt. The corrugated ribbon has a resistance of only a fraction of an ohm; therefore, the matching

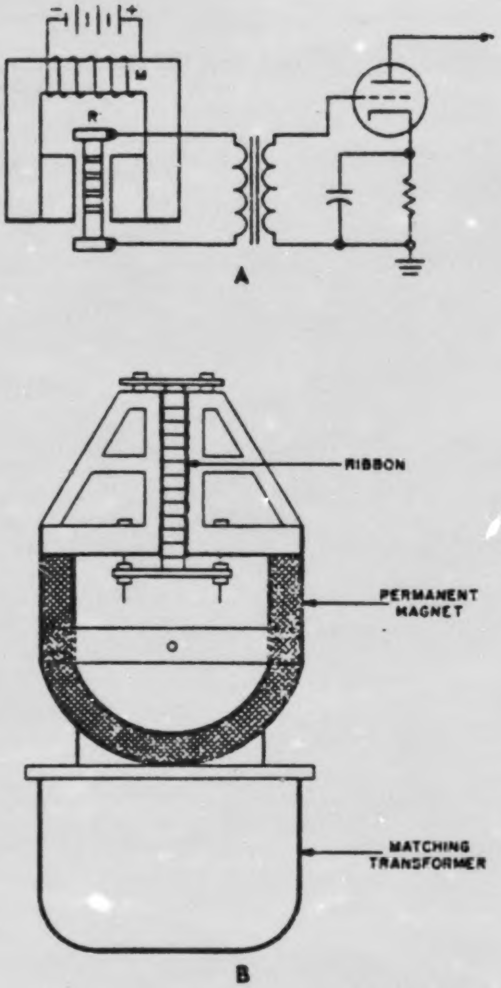

M
R
A
RIBBON
PERMANENT MAGNET
MATCHING TRANSFORMER
B

Figure 67. Velocity microphone (A) circuit diagram and (B) construction details.

transformer is usually built into the microphone to reduce losses. The frequency response is practically flat from 30 to 15,000 cps. The low impedance of the velocity microphone permits a long cable connection to the amplifier, but the cable must be well shielded because of the possibility of a-c hum pickup.

14-9. **Carbon.** The carbon microphone is widely used in intercommunications and cueing systems, and will be discussed more fully in Volume 2, Auxiliary Equipments. In the carbon microphone, a constant direct current is permitted to flow through a mass of carbon granules. As sound waves vibrate the diaphragm, its resultant motion alternately compresses and releases pressure on the mass of carbon particles. The changing pressure on the carbon causes the resistance value of the total mass to change, thus permitting

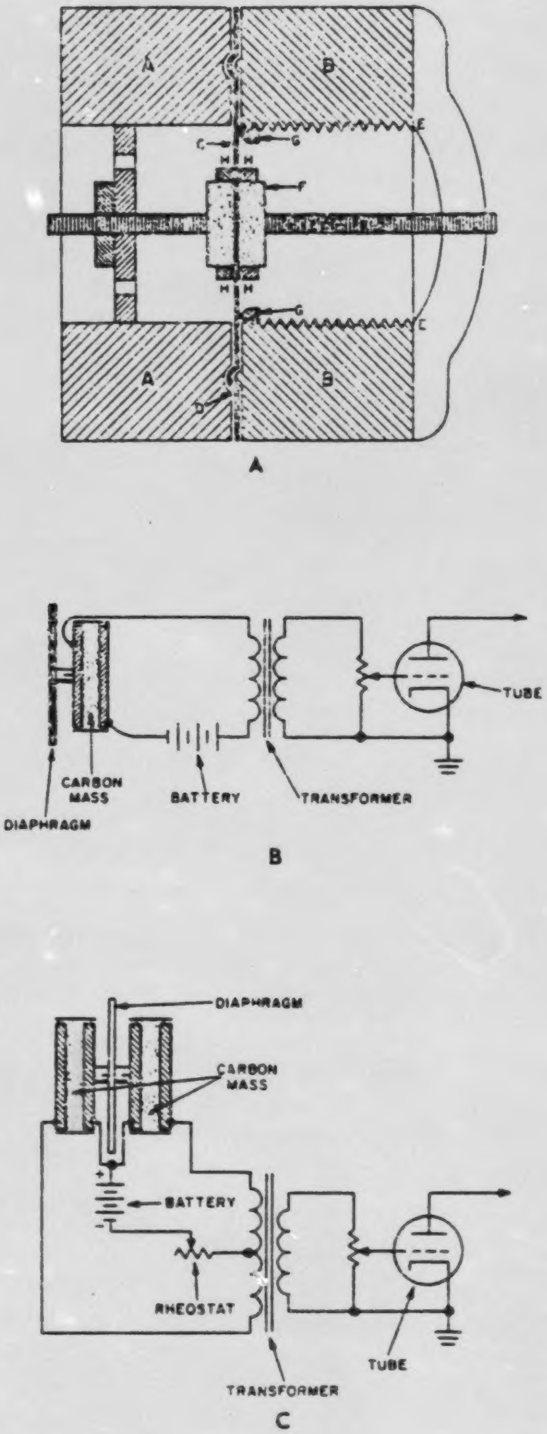

A
B
C
G
E
H
F
D
A
CARBON MASS
BATTERY
TRANSFORMER
DIAPHRAGM
TUBE
B
DIAPHRAGM
CARBON MASS
BATTERY
RHEOSTAT
TUBE
TRANSFORMER
C

Figure 68. Carbon microphone (A) cross sectional view, (B) single-button circuit diagram, and (C) double-button circuit diagram.

either more or less direct current passage. A cross section of a typical carbon microphone is shown in figure 68,A; A and B are heavy steel rings. The ridge in one and the groove, D, in the other hold the diaphragm, C, very tightly. The diaphragm is made of a very tough steel alloy and is generally designed to be from 0.001 to 0.002 inch thick. The small ring, G, is screwed into the large steel ring, B, to adjust the diaphragm tension so that its natural period of vibration will be above the desired audio-frequency range. The central portion of the diaphragm is gold plated on each side to insure good contact. The back of the microphone is closed except for a series of holes that permit the air and sound to reach the back of the diaphragm. The bridge, E, entends across the opening in the front of the microphone and supports the front carbon granule cup, or button, F. A similar one is supported by the back. These carbon cups, or buttons, do not touch the diaphragm and are partly filled with fine carbon grains. The size of these grains determines the sensitivity of the instrument, and soft felt washers prevent the carbon from getting out of the cup.

14-10. Figure 68,B, illustrates both the mechanical structure and the equivalent electrical circuit of the simple single-button carbon microphone. The single-button carbon microphone is characterized by high output level and ruggedness. It is practically unaffected by heat and humidity. When space and weight are limited in an installation, its high output is advantageous because fewer amplifier circuits will be required. The output ranges from 0.1 to 0.3 volt across a normal transformer impedance of 50 to 100 ohms.

14-11. To secure a more uniform response from various frequencies, the double-button type of carbon microphone, illustrated in figure 68,C, is generally used in place of the single-button type. As you can see, the diaphragm is placed between two cups which contain carbon grains. Vibration causes the grains of carbon on one side of the diaphragm to be compressed; at the same time, it causes the grains of carbon on the opposite side of the diaphragm to be loosened. This action permits more current flow through the first carbon button than through the second. The output voltage of the double-button carbon microphone ranges from 0.02 to 0.07 volt across a normal transformer impedance of 200 ohms.

14-12. The frequency response is uniform from 60 to 1000 cps. Above 1000 cps, the response increases rapidly, becoming more than 15 db higher at 2500 cps than it was at 1000 cps. The response then remains uniform up to approximately 6000 cps, where there is a marked falling off in response. Because of its poor response to the higher audio frequencies as well as its high noise level (hiss), the carbon microphone is not used extensively for general television purposes.

14-13. **Crystal.** The crystal microphone requires no energizing potential source such as the battery used with the carbon microphone. It requires no transformer or other coupling device. Its output, although not as high as the carbon microphone output, is adequate for direct application to the grid circuit of an amplifier. These features, plus its inherent simplicity and compact size, make this type of microphone unique among the devices designed to convert sound waves into electrical impulses.

14-14. Crystal microphones can be divided into two types—the diaphragm type and the sound cell type. The crystal element used in either type can be permanently damaged by high temperatures. This limits the number of useful applications. However, the crystal microphone is still widely used as a high-quality microphone for communications, both military and commercial. Figure 69,A, is a diagram showing the bimorph crystal unit; it can be seen that sound waves striking the diaphragm will cause the diaphragm to vibrate. These vibrations are transferred to the surface of the crystal by means of the connecting pin. The fidelity of this type instrument is approximately equal to that of most double-button carbon microphones; however, the frequency response extends to a much higher range. In the crystal microphone there is no background hiss or noise generated in the microphone itself. However, noise pickup on cables which are longer than 30 feet does limit the use of crystal microphones in television.

14-15. The sound cell is another type of crystal microphone. As shown in figure 69,B, the back-to-back crystal elements are inclosed within a rectangular bakelite frame sealed by two flexible membranes. No diaphragms are required in a sound cell microphone because the membrane imparts the sound pressure directly to the crystals, which produce the resultant a-c voltage.

14-16. **Capacitor.** A capacitor microphone generally consists of two electrodes separated by a very thin dielectric, usually air. One electrode is the diaphragm and the other is a rigid plate which has the same area as the diaphragm. The diaphragm motion changes the spacing between the two electrodes, varying the capacitance. If a d-c voltage is applied across this combination, the changes in spacing will produce changes in the capacitor charge which can be obtained as an a-c voltage. This device has a very linear pres-

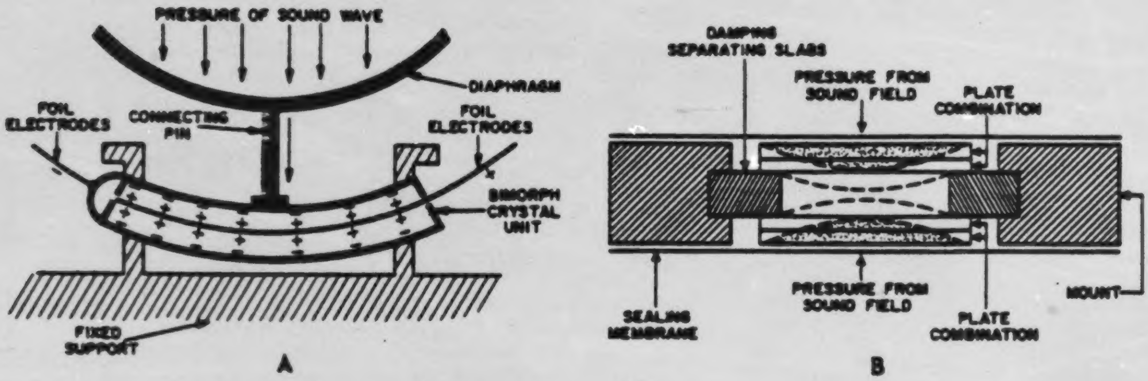

PRESSURE OF SOUND WAVE
DIAPHRAGM
FOIL ELECTRODES
CONNECTING PIN
FOIL ELECTRODES
BIMORPH CRYSTAL UNIT
FIXED SUPPORT
A
DAMPING SEPARATING SLABS
PRESSURE FROM SOUND FIELD
PLATE COMBINATION
MOUNT
PRESSURE FROM SOUND FIELD
SEALING MEMBRANE
PLATE COMBINATION
B

Figure 69. Crystal microphone (A) cross sectional view of diaphragm and crystal and (B) cross sectional view of single sound cell unit.

sure response and a wide frequency response; it can be easily tuned to higher resonant frequencies because the diaphragm is the only moving part. It has a good high-frequency response and is relatively insensitive to mechanical noise because of its stiffness of construction. The capacitor microphone requires an external power source and is adversely affected by high or changing humidity.

14-17. The output voltage will be small; therefore, amplification will be required and the leads must be kept very short to avoid picking up stray field noise. This type of microphone has not been used extensively because of the necessity for battery operation to avoid hum pickup. However, new developments with solid-state amplifiers built into the microphone housing have changed this situation.

14-18. **Comparison of Microphones.** The characteristics of the various microphones are summarized in figure 70, which lists the various major types of microphones, together with their output level in db and their frequency range in cycles per second. From the table, you can see that from the standpoint of output level the carbon type is best and from the standpoint of frequency range the velocity type is best.

14-19. **Adjustments and Maintenance.** It should be said that most of the difficulties with microphones are caused by misuse or careless handling. Nevertheless, let us mention a few adjustments that can be made on a microphone. The polydirectional microphone may be any of the basic types which have an adjustable aperture. When the aperture is fully open, the microphone has a bidirectional pattern; when the

MICROPHONE TYPE	FREQUENCY RANGE IN CYCLES	SIGNAL-TO-NOISE	EXAMPLES OF OUTPUT IMPEDANCE	AVERAGE DB OUTPUT	VOLTAGE OUTPUT
DYNAMIC					
MOVING COIL	30 TO 20,000	MEDIUM	LO-Z 30, 50, & 250 HI-Z 50K	-55 TO -60	0.00004V
RIBBON	30 TO 20,000	MEDIUM	250 OHMS	-55 TO -60	0.0002V
CARBON					
SINGLE-BUTTON	70 TO 6000	LOW	50 TO 100 OHMS	-45	0.3V
DOUBLE-BUTTON	60 TO 6000	LOW	200 OHMS	-35 TO -45	0.07V
CRYSTAL	UP TO 14,000	HIGH	5 MEG OHMS	-50 TO -60	
CAPACITOR	20 TO 15,000	HIGH	30,150 OR 600 OHMS	-53	

Figure 70. Comparison of microphones.

aperture is closed, the microphone is nondirectional. At shutter settings between the open and closed positions, the microphone is unidirectional. Some microphones are designed with blast filters which are adjustable and require settings commensurate with the operating conditions.

14-20. The maintenance of microphones will not be so much in the microphone itself, but rather in the cords and connectors. If, for instance, you were told a carbon microphone did not have an adequate output, the first thing you should check is the carbon granules for a "packed" condition. This condition is caused by excessive current which causes the carbon granules to stick. Carbon granules that are packed can sometimes be loosened if you turn off the applied current and shake the microphone while holding it in various positions. If this does not correct the situation, you may have to replace the carbon granule mass. Do not shake a dynamic microphone as this will not accomplish anything desirable and may damage the internal unit.

15. Audio Amplifiers

15-1. We know that audio frequencies range from about 15 cps to 20 kc. TV equipments that amplify signals for sound reproduction employ amplifiers designed for this low-frequency range. It is the task of such amplifiers to strengthen the audio signal and reproduce it faithfully. The dominant requirements are, therefore, gain and fidelity. In this section we will discuss how these requirements are met with transistor amplifier. These amplifiers and the principles involved are very similar to electron-tube audio amplifiers. Your knowledge of tube amplifiers will enable you to make comparisons as we progress from the general characteristics to specific types of audio amplifiers. We will distinguish between preamplifiers, drivers, and power amplifiers. Illustrated circuits will be described and the effects

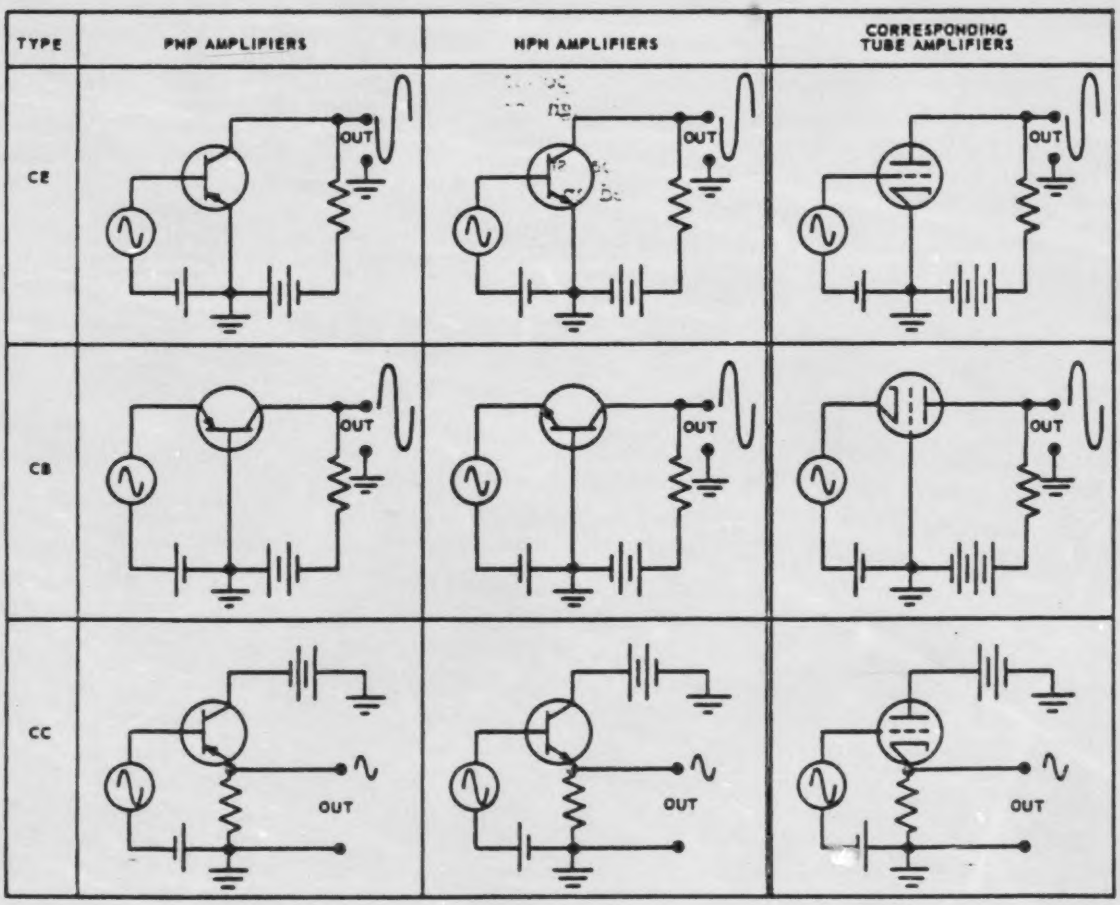


Figure 71. Basic transistor amplifier circuits and the corresponding electron-tube versions.

ITEM	CE AMPLIFIER	CB AMPLIFIER	CC AMPLIFIER
INPUT RESISTANCE	300 - 2000 OHMS	10 - 300 OHMS	20K - 300K OHMS
OUTPUT RESISTANCE	5K - 50K	100K - 500K	50 OHMS - 5K
VOLTAGE GAIN	300 - 1500	500 - 2000	LESS THAN 1
CURRENT GAIN	25 - 50	LESS THAN 1	25 - 50
POWER GAIN	25 - 40 DB	20 - 30 DB	10 - 20 DB

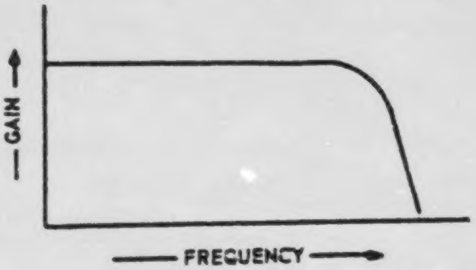
Figure 72. Table of typical value ranges for the CE, CB, and CC amplifiers.

of bias adjustments will be explained for push-pull amplifiers.

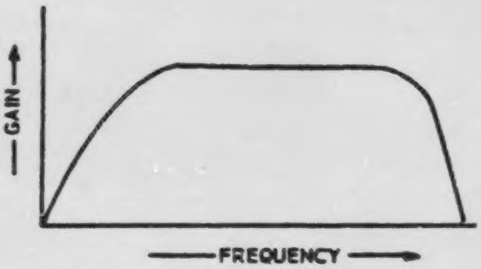
15-2. **General Characteristics.** All three transistor configurations are used in audio amplifier circuits. The basic circuits are shown in figure 71. Note that these transistor amplifiers are the counterparts of well-known electron-tube amplifiers. Although transistor amplifiers have lower input and output impedances than have electron-tube amplifiers, the CE, CB, and CC amplifiers have impedance characteristics corresponding to those of the grounded-cathode, grounded-grid, and grounded-plate (cathode follower) amplifiers, respectively. Note in figure 72 the range of values that can be generally expected for input and output impedances of transistor amplifiers. Also note in this figure the different ranges of current, voltage, and power gain that are obtainable for each type of amplifier. This should give you an idea of their sensitivities.

15-3. *Coupling.* The fidelity of an audio amplifier can be improved or impaired by the coupling. As with electron-tube amplifiers, coupling can be put into four main categories: (1) direct, (2) RC (resistance and capacitance), (3) transformer, and (4) impedance coupling. However, it must be realized that the impedance values for transistors are considerably lower than for tubes.

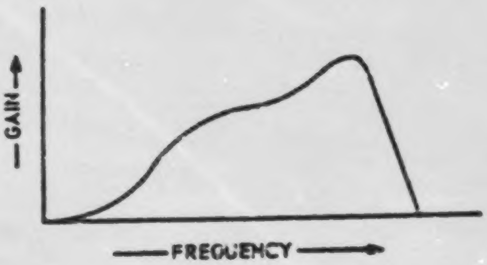
15-4. When impedance matching is satisfactory, we can use either direct or RC coupling. As shown in figure 73,A, direct coupling gives an excellent low-frequency response, thus indicating high fidelity from zero cps (d-c) upward through the audio range. The upper frequency limit (half-power point, 3 db below midfrequency gain) is dependent upon the shunting capacitances of the amplifier. The same is true for the RC-coupled amplifier with regard to its upper frequency limit (see fig. 73,B). Its lower frequency limit (half-power point) is established primarily by the size of the coupling capacitance. Since the coupling capacitive reactance increases as frequency decreases, low frequencies are attenuated. Thus, gain falls off toward



A DIRECT COUPLING



B RC COUPLING



C UNTUNED COUPLING

Figure 73. Typical response curves for various types of coupling.

zero cps as indicated by the response curve, figure 73,B. RC coupling is used when d-c must be blocked (not coupled).

15-5. Untuned impedance (LC) coupling or transformer coupling blocks d-c as does RC coupling. Transformer coupling has the added capability of matching impedances. Recall from your knowledge of transformers that the primary "sees" the secondary impedance times the turns ratio squared of the transformer:

$$Z_1 = \left(\frac{N_1}{N_2}\right)^2 Z_2$$

Therefore, by means of a transformer, the impedance reflected into the amplifier circuit can be made to have a value that produces the desired gain. We note in figure 73,C, however, that the frequency-response curve is not flat for untuned LC or transformer coupling. This is because the impedance is frequency-dependent, inductive for low frequencies and capacitive for high frequencies.

15-6. *Load.* The load impedance of an amplifier is usually resistive throughout most of its operating range. As is the case with electron-tube amplifiers, gain is a function of load. The plots depicted in figure 74 are representative of the curves of gain for the three transistor configurations. Noteworthy are the following facts:

- Highest current gains A_i are obtained for low values of load resistance. (CE and CC amplifiers yield substantial current gains. For the CB amplifier it is always less than one.)

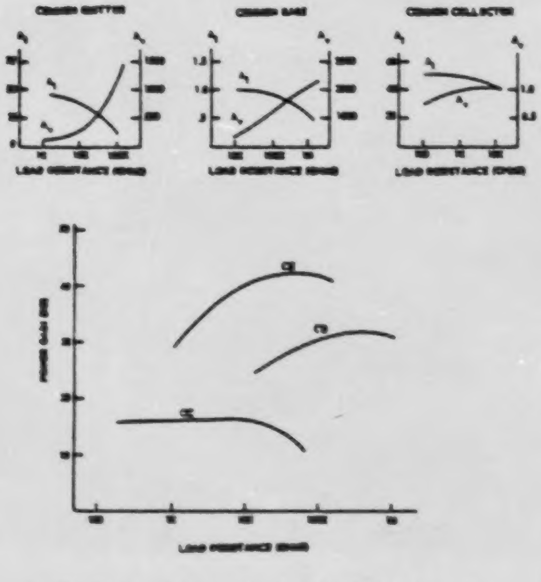


Figure 74. Gain versus load resistance curves.

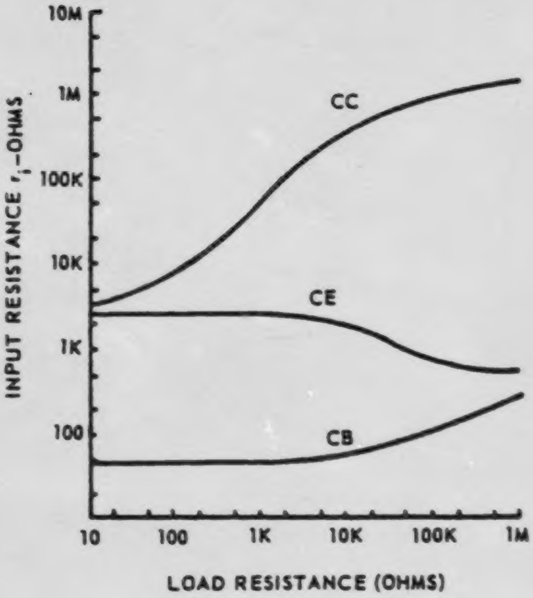


Figure 75. Input resistance versus load resistance curves.

- Highest current gains A_v are obtained for high values of load resistance. (CB and CE amplifiers produce appreciable voltage gains. For the CC amplifier it is always less than one.)
- Highest power gain G occurs when the product of the current and voltage gain is greatest. Since the CE amplifier has both high current gains and high voltage gains, its power gains are necessarily the highest.

15-7. A study of the curves in figure 74 will give you an appreciation of the advantages offered by each configuration. It is of interest to observe in figure 75 that the input impedance is also a function of load impedance. This should be expected since we know that the input is not independent of the output for transistor amplifiers. Note how greatly the input resistance of the CC amplifier varies with load resistance.

15-8. **Preamplifiers.** Audio preamplifiers are designed to increase the gain of low-level signals from transducers such as microphones and recorder-reproducer heads. They are operated class A at power levels in the order of micromicrowatts or microwatts. Since the signals are so very small, special attention must be given to the noise factor, input impedance, and coupling.

15-9. *Noise factor.* Generally speaking, transistors are noisier than tubes. However, junction transistors can be fabricated to operate with noise factors comparable to tubes (3 to 5 db).

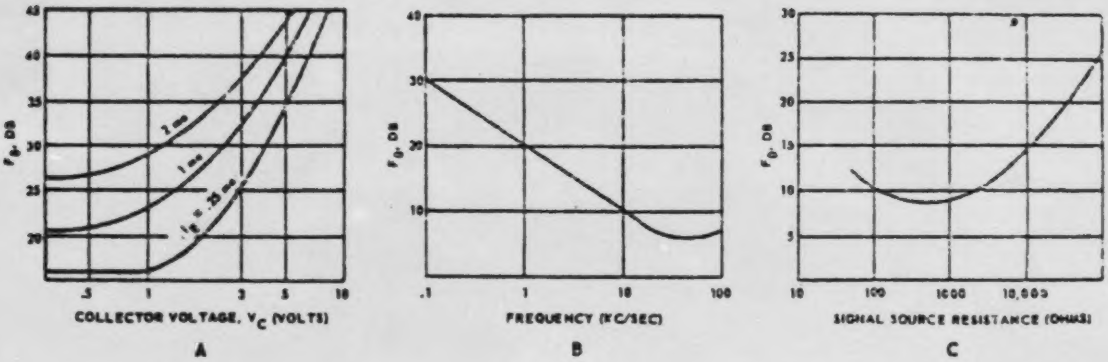


Figure 76. Typical curves showing how the noise factor of a transistor preamlifier is affected by (A) collector voltage and emitter current, (B) frequency, and (C) signal source resistance.

The noise factor is affected mainly by the operating point, the signal frequency, and the signal source resistance.

15-10. The curves in figure 76,A, show that the noise factor changes with collector voltage V_{CE} and emitter current I_E. Notice how rapidly the noise factor increases as V_{CE} is raised above 2 volts. Increases in I_E have a less marked effect, but nevertheless depreciate the quality. Consequently, the operating point of a preamplifier is selected so that both V_{CE} and I_E are quite low in value.

15-11. Note in figure 76,B, how the noise factor is dependent upon the signal frequency. The poorest (highest) noise figures occur at the lower end of the audio range. They continue to improve as frequency increases well beyond the upper limit of the audio frequencies, 20 kc. Above 50 kc, however, they gradually become worse.

15-12. The variation of noise factor as a function of signal source resistance is shown in figure 76,C. This curve indicates that the best (lowest) noise factors result when the signal source has a resistance between 100 and 2000 ohms.

15-13. *Input resistance.* Since, to obtain a low noise factor, it is desirable to use a signal source resistance in the range of 100 to 2000 ohms, the amplifier's input resistance should also

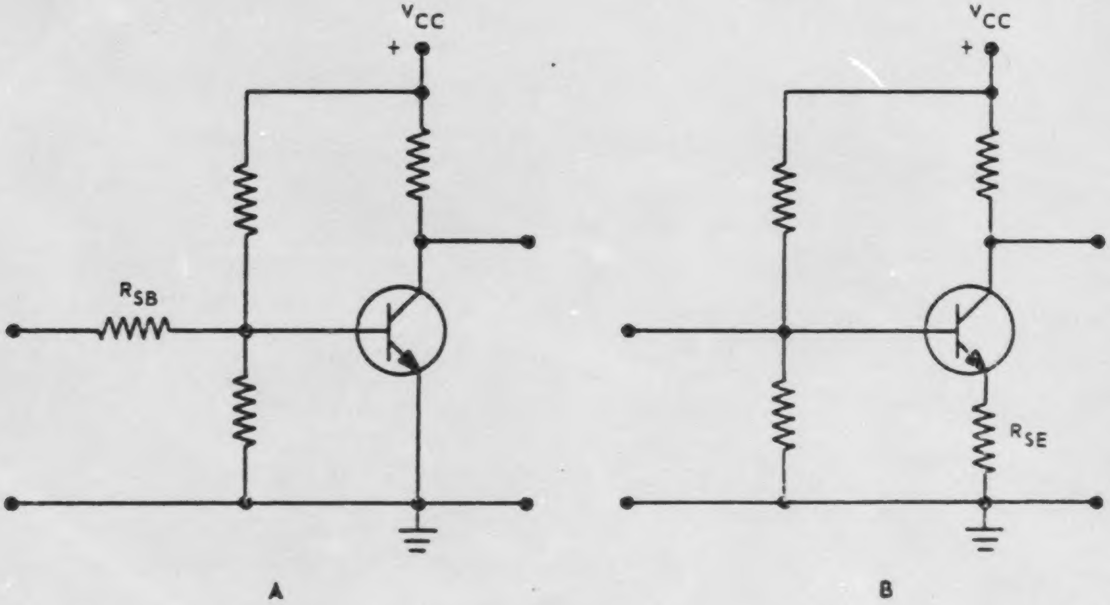


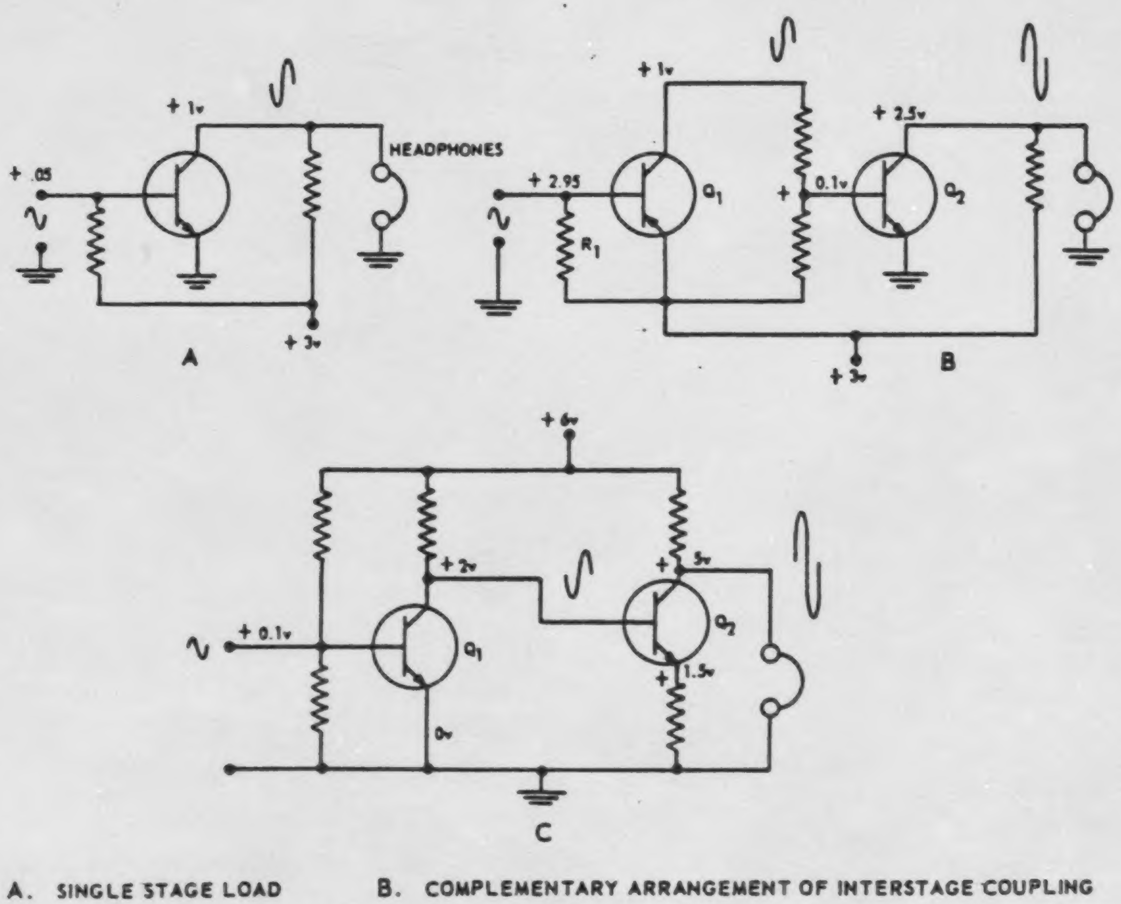
Figure 77. Two ways of increasing the input resistance of a CE amplifier.

be within this range. Recall that maximum power transfer occurs when the source resistance and load resistance are equal. In this case, the amplifier input resistance is the load resistance.

15-14. Both the CB and CE amplifiers have input resistances within the desired range (see fig. 72). The CB amplifier is used when a very low input resistance or a high output impedance is wanted. When the input resistance of a CE amplifier is satisfactory, this type amplifier is generally preferred because of its higher power and current gain capability.

15-15. If it is necessary to use a signal source of high resistance, such as a crystal pickup head, a high input resistance preamplifier is needed. Since the CC amplifier has a high input resistance (20K ohms to 800K ohms), it can be readily matched to the source. There is a disadvantage, however, inherent in this amplifier. Its input resistance changes greatly with small variations of load (as shown in fig. 75). The CE amplifier does not have this drawback but its input resistance is ordinarily less than 2000 ohms. Fortunately, its input resistance can be made as high as 20,000 ohms in one of two ways: (1) by placing a large resistor R_{BB} in series with the input to the base (see fig. 77,A) or (2) by inserting a small resistor R_{BE} in series with the emitter (see fig. 77,B). Both ways attenuate the signal input, but the CE amplifier has a notably high gain to overcome this loss.

15-16. *Coupling.* Direct coupling will give excellent low-frequency response down to zero cps (see fig. 73,A). Some basic circuits are illustrated in figure 78. The bias values shown should be regarded as representative. Figure 78,A, shows a simple amplifier that has its output signal directly coupled to headphones. In figure 78,B, we see two stages of amplification.



A. SINGLE STAGE LOAD B. COMPLEMENTARY ARRANGEMENT OF INTERSTAGE COUPLING

C. DIRECT COUPLING OF AMPLIFIERS HAVING LIKE TRANSISTORS (NPN TYPES ILLUSTRATED)

Figure 78. Direct coupling.

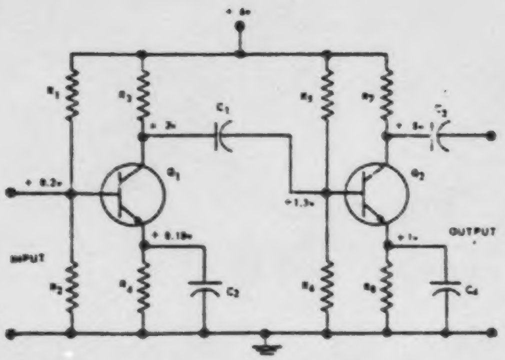


Figure 79. Interstage RC coupling.

The first stage uses a p-n-p transistor, whereas the second stage uses an n-p-n transistor. This circuitry is said to be complementary. Note that the n-p-n obtains its base bias from the p-n-p stage. Another two-stage circuit is shown in figure 78,C. The bias is not obtained by a complementary arrangement. Both Q1 and Q2 are n-p-n transistors. A resistor in series with the emitter of Q2 is used to establish the desired operating point for the second stage. Since this resistor is unbypassed, there is signal degeneration. Thus, gain is reduced, but stability is enhanced.

15-17. Stability is generally a problem whenever direct interstage coupling is employed. This is because any d-c change in one stage is coupled into the next stage and amplified.

15-18. A simple way to prevent the transfer of d-c variations from one stage to the next is to use RC coupling. A two-stage RC-coupled amplifier is illustrated in figure 79. The capacitor C1 blocks d-c, but couples a-c from the collector of Q1 to the base of Q2. Since, however, capacitive reactance increases as frequency decreases, the lower frequencies of a-c are attenuated. Consequently, gain falls off to zero cps (fig. 73,B). The principles pertaining to RC-coupled electron-tube amplifiers apply to transistor amplifiers also. The low-frequency half-power point depends upon many factors: the electrical size of the coupling capacitor, the load impedance of the input impedance of the following stage, and the emitter resistor bypass capacitor. Capacitors C1 and C3 should be as large as feasible; C2 and C4 should be large enough to prevent low-frequency degeneration.

15-19. Untuned transformer coupling also provides d-c isolation of the stage. The trouble with this type of coupling is its poor low-frequency response. This can be corrected by the inclusion of a low-frequency compensation circuit. In figure 80, the components R_0 and C_{LF} present a higher load impedance to the low frequencies than to the highs. This effectively boosts the power of the low frequencies to give a more uniform gain response (see fig. 80,B).

15-20. **Driver and Power Amplifiers.** Amplifier stages designed primarily to raise the power level of the signal are known as driver and power amplifiers. Driver stages usually develop power in the order of milliwatts. Power amplifiers develop watts or hundreds of milliwatts of power. This distinction based on power levels is approximate at best. The power levels of driver and power amplifiers depend on the equipment in which they are used. A driver amplifier, as its name implies, is used to drive a succeeding stage. Thus, the driver stage delivers power to another driver stage or to a power amplifier. Power amplifiers build the signal

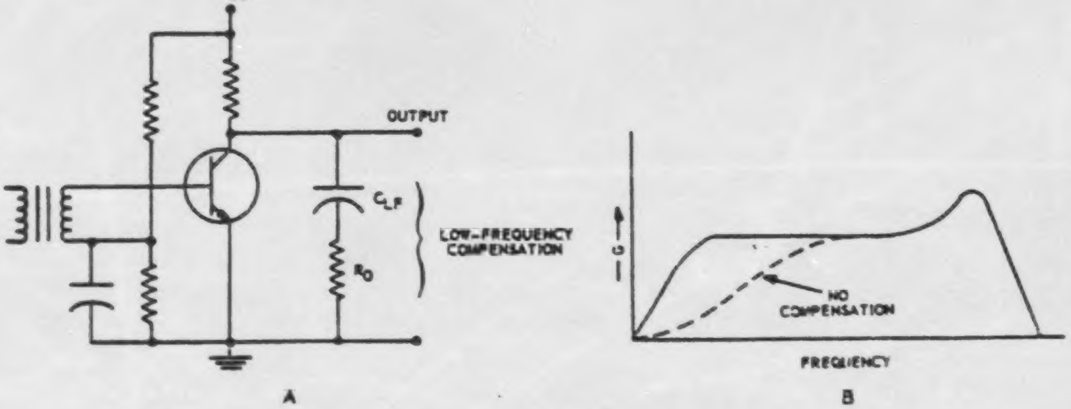


Figure 80. Transformer coupling with low-frequency compensation.

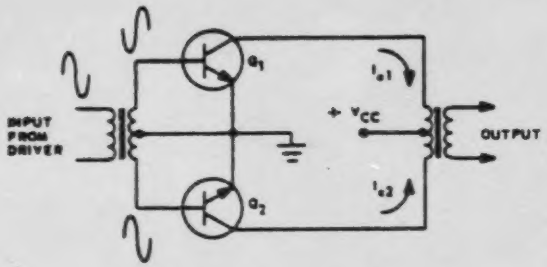


Figure 81. Class B push-pull amplifier.

power to the necessary level to operate a device such as a speaker.

15-21. *Single-ended.* Circuit arrangements for single-ended driver and power amplifiers do not differ to any marked degree from the class A preamplifiers just covered. Drivers and power amplifiers operate at higher collector voltages and currents, however, and are carefully matched for power transfer. Transformer coupling is very useful for matching. Such coupling also improves efficiency since the d-c losses are reduced. Impedance coupling (LC) is sometimes used to obtain a higher efficiency, but it has poor low-frequency response.

15-22. Efficiency is quite important at high power levels so it is a matter of concern, particularly for power amplifiers. As long as we operate class A, efficiency will be poor. If single-ended amplifiers are used, there is no choice; fidelity demands linear class A operation.

15-23. *Push-pull.* Fidelity can be realized at higher efficiencies by a push-pull circuit arrangement. Improved efficiency and fidelity can be attained with push-pull amplifiers operating class A. Just as in the case of electron-tube push-pull operation, even-harmonic distortion is minimized. If the circuit is perfectly symmetrical, such distortion is completely eliminated. Because of this fact, push-pull amplifiers can deliver greater power for an allowable amount of distortion than can two single-ended amplifiers. Moreover, push-pull amplifiers can be operated class B and class AB since even-harmonic (nonsymmetrical) distortion can be canceled. Provided there is good circuit symmetry, excellent linearity can be achieved with class AB operation and fairly good linearity is possible with class B operation.

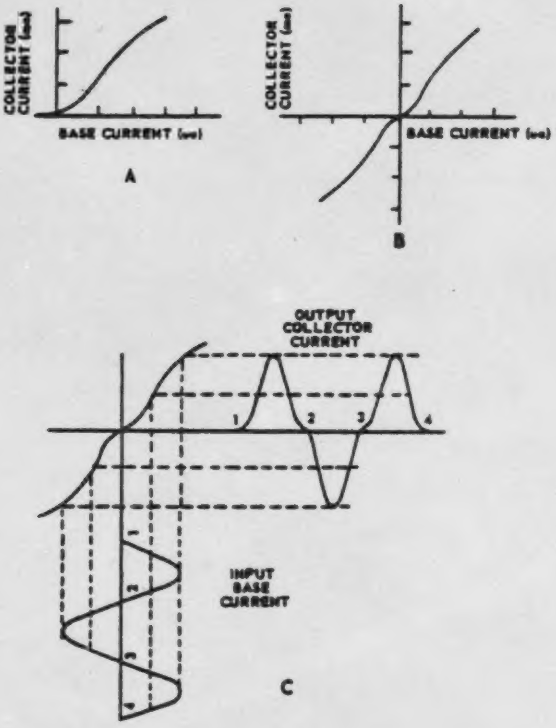
15-24. Because of its simplicity, let's begin with a class B transformer-coupled type. Note that the circuit shown in figure 81 resembles closely the corresponding electron-tube class B push-pull amplifier. Again we have chosen n-p-n transistors to bring out this similarity. Remember that p-n-p transistors can be used instead, provided the bias polarities are reversed. This goes without saying for all transistor circuits.

15-25. Observe in figure 81 that there is no forward base-emitter bias; both the base and emitter of Q1 and Q2 are at d-c ground potential. Therefore, Q1 and Q2 are cut off; with no-signal input (the static condition) $I_{c1} = 0$ and $I_{c2} = 0$.

15-26. A signal applied to the primary of the input transformer will produce signals at opposite ends of the center-tapped secondary 180° out of phase as shown. Therefore, when the base of Q1 "sees" a negative alternation, the base of Q2 "sees" a positive alternation, and vice versa. Because both Q1 and Q2 have zero volts base-emitter bias, each will conduct during positive alternations and remain cut off during negative alternations. Since their inputs are 180° out of phase, Q1 is conducting (I_{c1}) while Q2 is cut off, and Q2 is conducting (I_{c2}) while Q1 is cut off. In other words, Q1 and Q2 conduct alternately to supply output current ($I_{c1} + I_{c2}$) throughout the entire cycle (360°).

15-27. This circuit arrangement amounts to having two symmetrically arranged single-ended amplifiers supplying a common load. Figure 82,A, is a dynamic curve of a single-ended amplifier. Figure 82,B, is the dynamic curve of a push-pull amplifier; note that this curve is merely the combination of the dynamic curves of two single-ended amplifiers. Because of the 180° phase relationship of the input and the circuit arrangement, the positive direction of base currents I_{b1} and I_{b2} are opposite; also, the positive direction of collector currents I_{c1} and I_{c2} are opposite. The input signal wave is protected on the dynamic curve diagram in figure 82,C. We see that the output waveshape is the composite of the current I_{c1} and I_{c2}, as previously explained. This diagram is useful inasmuch as it depicts clearly the accuracy of signal reproduction, thus fidelity. Note the distortion that occurs as the signal approaches and passes through zero. This is called *crossover distortion.* The output wave contains odd harmonics of the signal frequency.

15-28. Crossover distortion can be eliminated by biasing Q1 and Q2 in the forward direction. A simple biasing arrangement is illustrated in figure 83. The resistor R is made variable so that we can adjust the bias for class AB operation or class A operation. If properly adjusted for class AB operation, the crossover effect is not evident in the output. A comparison of figure 84,A, and figure 84,B, shows why this is so. The nonlinearity is effectively canceled and ex-



A. DYNAMIC CURVE OF A SINGLE TRANSISTOR
B. DYNAMIC CURVE OF PUSH-PULL ARRANGEMENT
C. WAVEFORMS

Figure 82. Class B push-pull curves.

cellent fidelity achieved. If R is adjusted for class A operation, the output waveshape is the resultant of the individual waveshapes as illustrated in figure 84,C.

15-29. It seems that since class AB operation is more efficient than class A operation, class AB would always be preferred. The output waveshape looks as good for class AB as it does for class A. This is because we have assumed perfectly matched transistors and symmetrical circuitry. Suppose, however, that the transistors are not perfectly matched or that the circuit is not perfectly symmetrical; the dynamic curves for Q1 and Q2 would no longer be identical. For such a condition, the outputs from a class AB and a class A push-pull amplifier are shown in figure 85,A, and 85,B, respectively. It is quite obvious that the output for class AB operation is distorted. This nonsymmetrical distortion is a result of the presence of even harmonics. Thus, we need to realize that class AB operation requires matched transistors and circuit symmetry if high fidelity is desired. Such requirements somewhat offset the higher efficiency it offers.

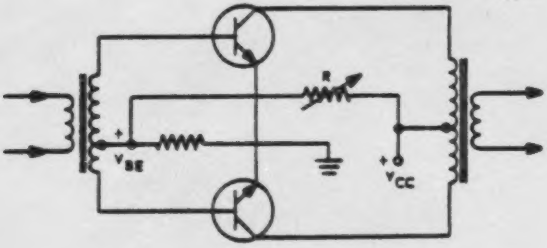


Figure 83. Push-pull amplifier that can be biased class AB or class A.

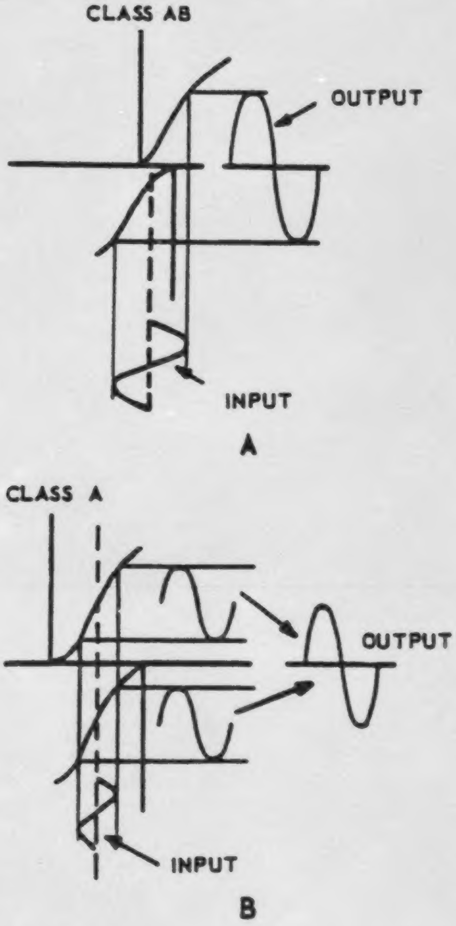


Figure 84. Typical output waveforms.

15-30. *Inverter driver.* It is not necessary to use a transformer to obtain input signals of opposite phase for a push-pull amplifier. The circuit in figure 86 shows how a driver amplifier can be designed to produce output signals that are 180° out of phase. Resistors R1 and R2 are of such ohmic values as to provide the proper base bias for linear class A operation. Resis-

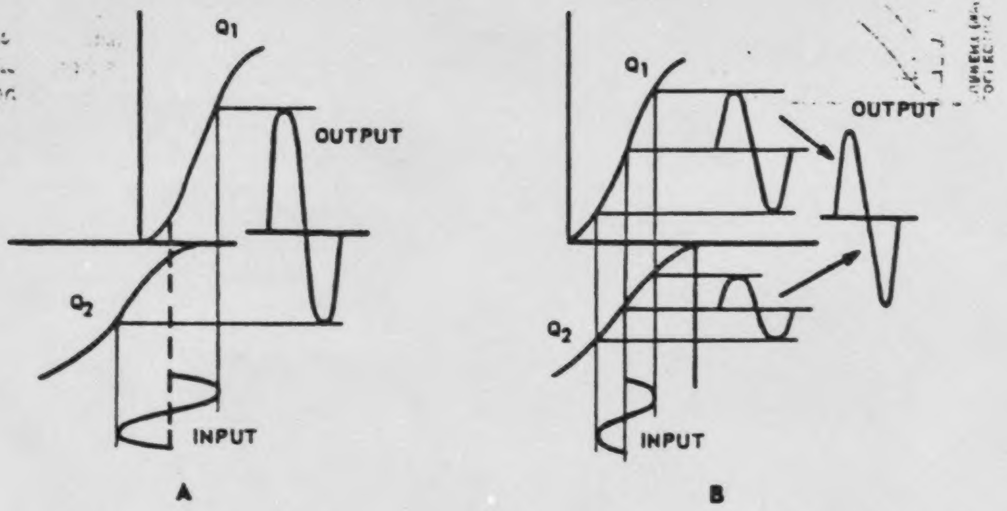

Q1
OUTPUT
Q2
INPUT
A
Q1
OUTPUT
Q2
INPUT
B

Figure 85. Waveforms resulting when a push-pull circuit is not symmetrical for (A) class AB operation, and (B) class A operation.

tors R3 and R4 are equal in value so that the signal outputs are the same in amplitude. The normal phase inversion from base to collector occurs across R3, whereas across R4 the signal output is in phase with the input.

15-31. Emitter follower action accounts for the phase of the signal across R4. This action also accounts for the fact that input impedance is higher than ordinary and the output impedance is lower to match the input impedance of the push-pull stage. Another advantage offered is the improved frequency response. Better frequency response can be attributed to two things: degenerative (negative feedback) action and capacitive coupling.

15-32. We took care to say capacitive coupling rather than RC coupling since crystal diodes CR1 and CR2 are used in place of resistors. These are discharge diodes that prevent the capacitors C1 and C2 from taking on a charge

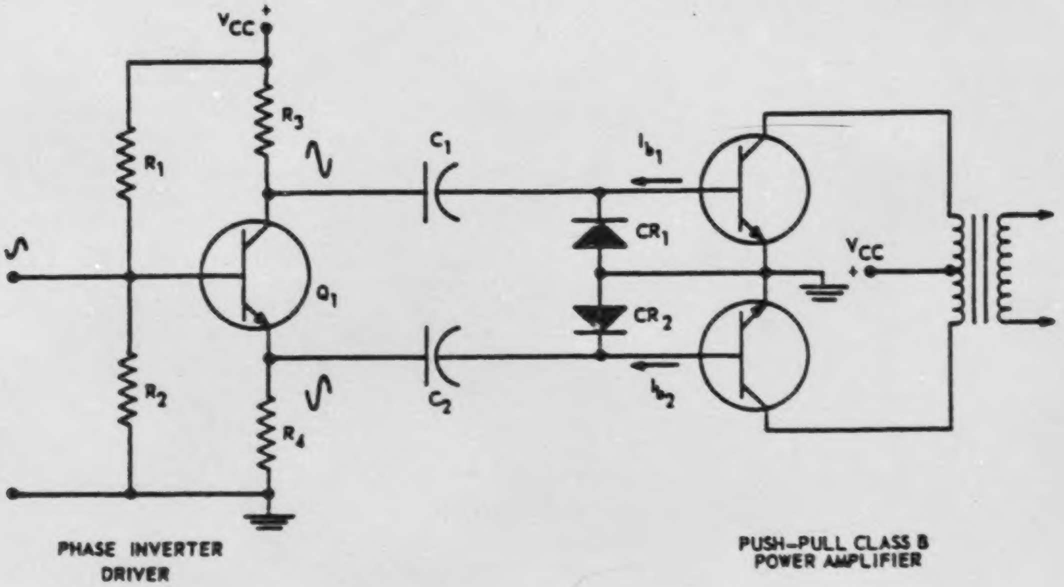

VCC
R1
R3
C1
Ib1
CR1
VCC
Q1
CR2
R2
C2
Ib2
R4
PHASE INVERTER DRIVER
PUSH-PULL CLASS B POWER AMPLIFIER

Figure 86. Capacitively coupled input to a push-pull amplifier.

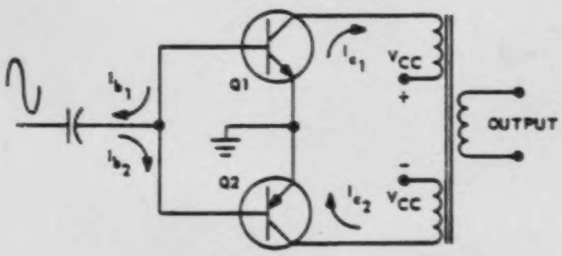


Figure 87. Push-pull amplifier using complementary symmetry.

which would bias the push-pull amplifier well below cutoff. Inasmuch as the transistors draw base current during half a cycle for class B operation, rectified base currents flow into C1 and C2. If CR1 and CR2 were not connected in the circuit as shown, a negative charge would build up to reverse-bias the push-pull transistors. This would correspond the grid-leak biasing electron tubes. To preclude this unwanted base biasing, CR1 conducts whenever C1 becomes negative with respect to ground, and CR2 conducts whenever C2 becomes negative with respect to ground. Thus, these discharge diodes function to maintain zero volts base bias.

15-33. *Complementary symmetry.* An arrangement made possible by the use of an n-p-n and a p-n-p transistor is shown in figure 87. This simple push-pull amplifier circuit affords the benefits of capacitive coupling, yet does not require a phase inverter and does not require discharge diodes.

15-34. Input phase inversion is unnecessary since at zero base bias the n-p-n transistor (Q1) and p-n-p transistor (Q2) conduct on alternate half-cycles of the input. When the input signal is positive going, Q1 conducts and Q2 is cut off. When the input signal is negative going, Q2 conducts and Q1 is cut off. Thus, push-pull operation takes place as a result of the complementary action of the transistors.

15-35. Note that I_{b1} and I_{b2} flow in opposite directions. If the transistors are properly matched, these two currents will be equal. Because they are equal and opposite, the resultant charging current flowing into the coupling capacitor is zero. Since no charge will develop to reverse-bias the bases, discharge diodes are not needed.

15-36. The basic circuit just discussed illustrates how simplicity and improvement of a push-pull amplifier circuit can be attained by using n-p-n and p-n-p transistors together. Many varied circuits take advantage of the complementary features of transistors. Such circuits have no electron-tube counterparts.

16. Audio Consoles

16-1. The audio console is the nerve center for the audio portion of TV production, just as the sync generator is the heart of the video equipment. However, the basic functions are vastly different. Whereas the sync generator provided a standard, the audio console does much more. In this section we shall see just how much more as we study the functions, signal paths, mixing action, and monitoring facilities which are all a part of the audio console. An audio console will be designed to handle audio signals from microphones, tape recorders, special effects consoles, and other sources as necessary for sound production.

16-2. **Functions.** There are many functions which could be listed; however, for our purposes, we will consider those functions performed by amplifiers, switches, mixers, and monitors. Of course for the console to carry out its functions there must be certain auxiliary equipment attached, as indicated by the various input and output terminations of figure 88. Most consoles contain their own power supply.

16-3. *Amplifiers.* In an earlier part of this chapter when microphones were discussed, you will recall that the dynamic microphone was determined to be the best for fidelity. This microphone, however, requires a preamplifier (preamp) due to its low output voltage. Therefore, the audio console has built-in preamplifiers, which give sufficient signal level to drive the program and monitor amplifiers. The preamps used in this unit (see fig. 88) have external gain controls, which are located on the front of the console along with the other input controls. These controls are actually labeled "mixer." The program amplifier is also a multistage amplifier which falls in the class of a driver. This amplifier also has a gain control, which is the master control that enables the operator to adjust for the correct output level, as indicated on the VU meter.

16-4. *Switches.* The control consoles are equipped with a number of multiple contact double throw lever switches. These switches are used to perform a number of functions, some singly and some as multiple functions. The tape input is an example of a single function. When the switch is in either the program or monitor position, the only function is applying the tape signal to the respective amplifier. The microphone selector switches use an additional set of contacts to control the muting relay which removes the monitor speaker from the circuit. Also, the muting relay controls the on-the-air alert light.

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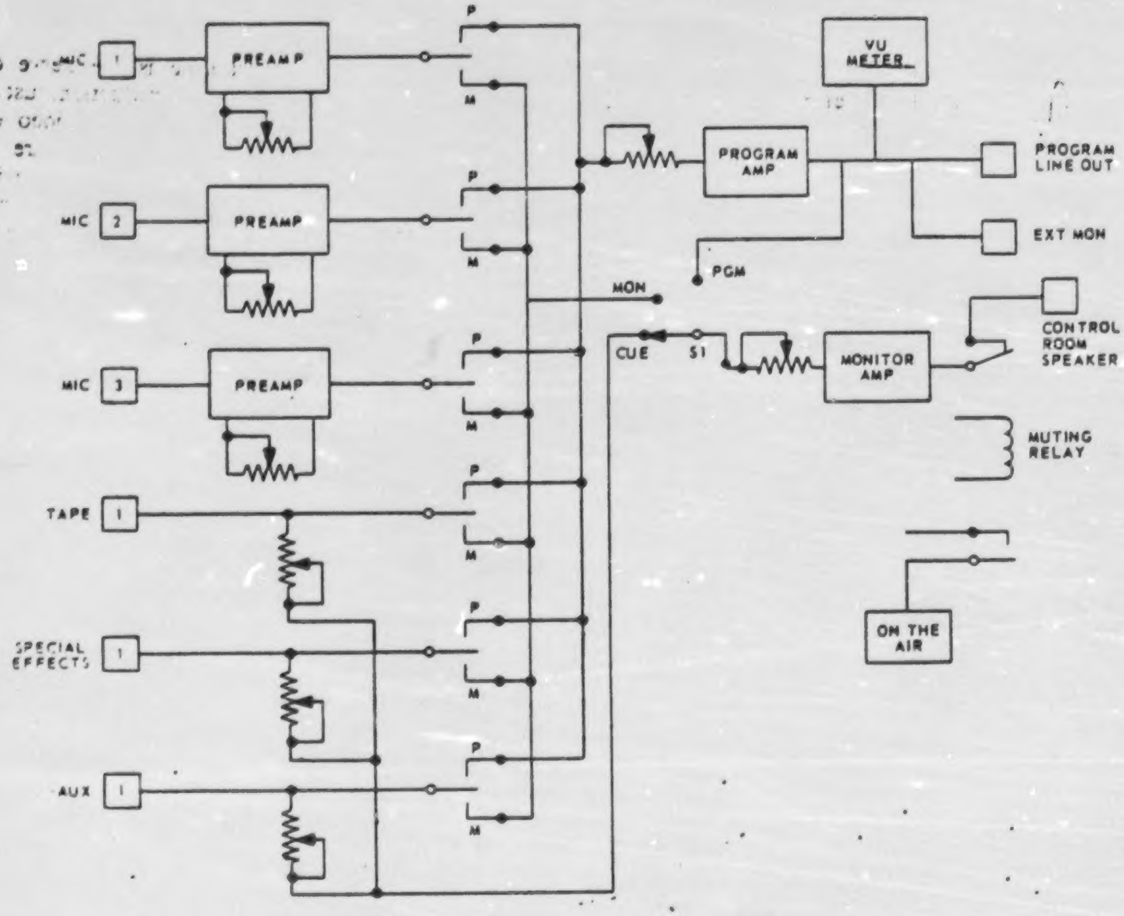


Figure 88. Block diagram of an audio console.

16-5. There are other switches, such as S1, which are used to select the various circuits to be monitored. There is a switch, not shown in figure 88, which enables the operator to select what he wishes to monitor on the phone jack. It should be mentioned that figure 88 is a block diagram of a simple console; the more elaborate control consoles have many more switches.

16-6. *Mixers.* The mixers consist primarily of the variable attenuators which are incorporated with the various amplifiers. In the amplifier circuits, the mixers are nothing more than gain controls. In the tape input, auxiliary input, and special effects, they serve as gain controls for the cue circuit. For those who have not actually worked on a control console, there might be some question as to why they are called mixers. This can best be explained by saying that as one input signal is used to replace another, one signal will be increased as the other is decreased. In this instance the operator will increase the gain on one input mixer control while decreasing the gain for the other. If two inputs are to be used at the same time, then the two mixer controls will be set to give the proper balance or desired mixing of the signals coming into the console. They will also be set to give the correct overall amount of output signal.

16-7. *Monitors.* The console incorporates a VU meter which is used to monitor the signal level out to the line and the external monitor. When you are using the mixer controls, the VU meter is very important for adjusting and maintaining the correct level out. The headset monitor (not shown on the block diagram) is also used for adjusting balance; however, since the operator's sense of volume is not good enough to set the level out, the VU meter is needed.

16-8. The various speaker connections also serve as monitors in the control room at remote locations and other miscellaneous installations. Like a headset, the speaker serves to give you an idea of the output level, but is not exact enough when adjusting for the correct level while monitoring tapes or live programs. It should be mentioned that some of the control consoles have selective scale adjustments for the meters, whereas others require modification of the pad circuit to change the meter scale.

16-9. **Signal Paths.** Again looking at figure 88, we see that there are a number of possible signal paths. In this diagram we have a total of six inputs and three outputs. Remember that this is a simple setup. There are many more inputs and outputs in the more elaborate setups that have talkback circuits incorporated for classroom work. In the diagram illustrated, start with microphone number 1 and trace a signal path through the preamp, level selector switch (program "P" position), program amplifier, VU meter, line out pad or extension monitor pad to the output. If switch S1 were in the PGM position, the output from the program amplifier would also be coupled to the monitor amplifier and control room speaker terminal.

16-10. As shown in the diagram, all of the input signals can be connected to the program amplifier and monitor amplifier at one time. Let us suppose that you have a studio program that requires the use of all the microphones and also requires specific sound effects which are recorded on tape. In this case, you must use the cue circuit to set the tape to a desired spot. With S1 in the cue position, a signal is fed to the monitor amplifier. At the right moment, you use the selector switch to send the signal to the program line. Thus, the tape input is mixed into and becomes part of the program.

16-11. **Performance Adjustments.** Three types of adjustments of primary concern are elimination of hum in the circuits, prevention of erratic action from switch contacts, and accurate control of output.

16-12. *Hum balance.* It should be mentioned at this point that hum is not usually a problem with a transistorized control console. However, the tube type consoles with a-c filaments are subject to hum distortion. To eliminate this problem, you will need to adjust the hum balance control, which is found in the power-supply section. To make the hum adjustment, set all input selector switches to the center or off position. If there is an input that cannot be turned off, it should be terminated in a resistance since it may pick up hum in a manner similar to an antenna. After all input circuits are either off or terminated, turn the master gain all the way clockwise. If the preamp is in the circuit following the selector switch, turn the preamp gain or mixer to minimum, fully counterclockwise. Now you are ready to adjust the hum control for minimum hum in the output of the program line.

16-13. *Switch contacts.* The switch contacts can be a source of much trouble due to their position in the line relative to the amplifiers. When a switch spring becomes bent, it will not close properly; therefore, you must adjust it for good contact. If a contact becomes burned or otherwise pitted, erratic action may result. Switch contacts should be carefully checked and adjusted or aligned for smooth action. This is true for both rotary and lever action switches.

16-14. *Overdriven output.* When setting up the output level, the important thing to remember is that your accuracy can be no better than the VU meter reading. In other words, you will not be able to properly set the output unless your VU meter is accurate. Depending on the console, you may find various methods of calibrating the VU meter. If you find the meter is improperly calibrated, it must be recalibrated against a known standard. In some cases it will be necessary to change the resistors in the pad circuit to get the correct VU meter calibration. You should realize the importance of output level control since this signal goes to a recorder, a live broadcast, or a live CCTV network. Therefore, any distortion which results from the overdriven output causes a loss of intelligence.

16-15. **Symptoms and Troubles.** The troubles diagnosed here are only a few that may cause the symptoms described. Some of the troubles may have many other symptoms which will enable you to determine the most likely cause of a malfunction.

16-16. *Hum.* As already mentioned, some of the hum problems are found in both transistor and tube-type sets. However, we know that troubles with hum are less frequent with transistor units because they do not use heater voltages. Most of the hum picked up in a transistor unit will be from the preamps, amps, long microphone leads, and other types of inputs. The tube-type control consoles are different because of the a-c filaments. The hum balance adjustment procedure has already been discussed in the previous section; however, this adjustment will suffice only if all components are in good condition. For example, if you attempt to make the hum adjustment and find that the control does not have any effect, there is another reason for the hum. In some models of the control console you will find the hum adjustment to be nothing more than a d-c voltage that can be varied from one side of the filaments to the other. In essence, this applies a positive potential on the filaments with respect to the cathode, causing a current flow from the cathode to the filaments rather than from filaments to cathode. Thus, any hum which might ordinarily be coupled from the filaments will be blocked. Now if you were not able to make the hum adjustment with the hum balance control, there is a good possibility that the voltage is missing from the hum balance adjust. Depending on the console model, you may have as much as 40 volts at the center tap of the balance control; this voltage is usually obtained from a bleeder circuit in the B+ supply. Therefore, when there is a hum control failure, you should check the power supply voltage and the balance voltage source.

16-17. *Feedback.* Recall that the muting relay is used to mute the speaker. If this fails, sound may be fed back from the speaker to the microphone. There are two possible places to look for the cause of this trouble—one is the relay which does the muting, and the other is the switch which controls the relay. Of course you can easily determine whether the switch is faulty by using another selector switch to see if the relay is activated. If the relay is activated and the speaker is muted, you know that the trouble is in the switch. If the relay is not activated, then it should be checked. Another thing to remember about sound feedback is that the higher audio frequencies will usually cause more difficulties than the lower frequencies. Also, do not overlook the possibility of sound feedback from extension monitors in adjacent rooms. These sources of sound can also be troublesome.

16-18. *Microphone.* Since the microphone is the signal source in an audio system, it can also be the source of troubles. The microphone in most all instances will require a preamp as indicated on the block diagram. There are many troubles that are attributable to the microphone itself, such as broken cords, loose connections, and corroded terminals—all of which could cause weak or erratic output. This is in addition to any other internal damage to the microphone; and, of course, any of these symptoms could be localized to the microphone by substitution of a known good microphone. If the trouble is in the preamp, then of course it would be a matter of checking tubes and other items or perhaps circuit tracing the preamp. However, a weak signal would usually be a weak tube in the circuit. Other possibilities, although less probable, are low B+, low filaments, component value change, and other minor items.

16-19. *Erratic mixers.* The mixer control is one part of the control console which is used extensively and causes some trouble during operation. The mixer or variable attenuator is, as you already know, nothing more than a gain control; therefore, it has a sliding arm contact. The sliding contact may become dirty and cause noisy operation of the control. This will be very apparent in the use of the control, as you will hear the static or jumps in gain rather than a smooth change. The trouble can be eliminated by cleaning the wiper arm contacts with a good contact cleaner, or some other cleaner as recommended by the manufacturer.

CHAPTER 7

Color Television

BESIDES THE natural appeal of color TV there are numerous practical advantages that account for its development and use. We will discuss its use in the Air Force, point out some of its advantages, and indicate its future utilization. Although a color TV system has much in common with a monochrome system, you should understand the special requirements for color TV. We will review these requirements before you study the camera chain and color monitor. Our coverage intends to reinforce your knowledge of color TV and to further your understanding of the principles involved. With the increased use of color systems, it is highly probable that you will have to maintain color TV equipment.

17. Applications and Requirements

17-1. Despite the complexity and expense of color TV, the Air Force employs it in many areas and is programing it for wider use. The more important areas of application are brought to your attention in this section before investigating the requirements of a color system.

17-2. **Air Forces Uses of Color TV.** The advantage to the Air Force of a color system over a monochrome system depends largely upon the nature of the subject matter being televised. Where color plays an important part in the delineation and recognition of the equipment or material being used, a TV system which will faithfully reproduce those characteristics is obviously desirable. The detail response of a color system is superior to that of a monochrome system. Because of the expense involved, a color system confined to one use only may not be advantageous. Usually a base or installation will have color facilities for application in a number of areas, such as weather, missiles, medicine, and others too numerous to list.

17-3. *Weather.* The use of color closed-circuit television in a base weather station is practical and greatly facilitates information transmission. Monochrome closed-circuit television has proved valuable in transmitting weather data to other interested facilities; color increases the quality of information which can be transmitted since weather charts and maps use several colors to denote highs, lows, fronts, etc. Accurate presentation of high-detail maps and charts demands good quality cameras. The addition of color eliminates some of the printed information on these maps, but conveys the same amount of information. Since the definition attainable with color TV is superior to monochrome TV, color is particularly suited to this application.

17-4. *Missiles.* Color television systems, like the monochrome systems described earlier in this volume, are also used to monitor the operations of guided-missile installations. Dangerous operations, such as missile launching and testing of machinery under extreme mechanical stress, require remote location of operators and supervisors; the extensive use of color coded controls and materials makes the color closed-circuit television monitoring system particularly effective. Inasmuch as small missiles can often be observed in relative safety from short distances, TV monitoring is not required; however, as a safety precaution, TV monitoring is necessary for large missile launching activities.

17-5. *Medicine.* Some major hospitals have installed color closed-circuit TV systems for medical training purposes. Recent developments in color TV equipment include a color camera especially designed for hospital use. The camera, with associated mirror and lights, can be remotely controlled from anywhere in the hospital. When properly located in the surgical room, the color camera permits large groups of medical students to view from a remote distance an entire operation in realistic detail. Autopsy rooms and dental clinics are other locations where direct observation is extremely difficult due to limited space. The use of color TV in these localities provides the same training capabilities as in the operating room. Such color systems have already proved to be of tremendous value in training medical students, and it seems reasonable to predict that the number of hospitals using color closed-circuit TV systems for this purpose will rapidly increase.

17-6. *Other.* General surveillance, hazardous monitoring, weather service, and training constitute the bulk of color closed-circuit TV applications. An example of tactical capabilities in the military application of TV is Air Force reconnaissance. A color closed-circuit TV link enables a large group of command personnel, located at a remote point, to observe the enemy terrain simultaneously with the pilot and observer, thus facilitating a more rapid transmission of vital information. Color TV, in this application, has a definite advantage over monochrome since camouflaged areas are more easily discovered when the picture is reproduced in color. Many colors that blend perfectly when viewed in monochrome stand out as being artificial in actual color.

17-7. **Requirements of Color TV.** To appreciate the requirements of a color TV system, you need to know the properties of color. Moreover, you need to know the perceptive characteristics of the human eye to understand what information must be contained in a color video signal. A brief review of color principles should suffice to call to mind those factors that have an important bearing on the compatibility, bandwidth, and sync requirements. We will show how these requirements are met when we describe the camera chain and monitors of a color system.

17-8. *Color and color perception.* The exact process by which the human eye is able to translate light of different wavelengths into color sensations is not fully understood. However, experiments have shown that almost the full range of color sensations can be obtained by mixing red, blue, and green light in various proportions. These three colors are called additive primaries. Additive primaries are not restricted to blue, green, and red. Any three colors can be used so long as no two of them produce the third when mixed. The widest range of color is obtained, however, when blue, green, and red are chosen. For this reason, these three additive primaries are used for color TV.

17-9. It is appropriate here to distinguish between additive and subtractive primaries. Additive primaries are so called because they are sources of color light which are added (mixed) to produce a desired color. By contrast, subtractive primaries are absorbers of color light which subtract or remove certain colors from white light to create color. Whereas a knowledge of subtractive primaries is important to several fields of study (e.g., photography and color printing), a knowledge of the additive primaries is more pertinent to the study of color TV.

17-10. A discussion of color as applied to color TV would be relatively simple if all that had to be considered were the various colors of light obtainable by mixing various proportions of blue, green, and red. But the variety of colors, called hue, is only one of the three basic properties of color perception. The other two properties that must be considered are saturation (or purity) and luminance (or brightness). Saturation is the term that describes the amount of white light mixed with the hue. For example, pink is a red hue diluted or mixed with a considerable amount of white. A zero saturation of red hue is white light, whereas a 100-percent saturation of red hue is pure red—thus no white light. Broadly speaking, the pale or pastel shades of hue are less saturated than the vivid shades of hue. Luminance is the term that describes the brightness or intensity of colored light. Although luminance, saturation, and hue are interrelated, they are distinct properties which you should understand.

17-11. A chart used for the study of color is the chromaticity diagram which reveals the relationships between the different colors and color mixtures. Figure 89 shows a chromaticity diagram which is useful to determine the hue and saturation required to produce a particular color. This tongue-shaped diagram is numbered around its perimeter from 400 to 700 millimicrons, which is the wavelength range of the visible spectrum. If figure 89 were in color, you could see that the color changes are gradual from point to point. The deep shades are present at the outer edge of the diagram. Any point on the perimeter represents a pure color (100 percent saturation). Moving inward to the white area, the colors become lighter; pastel shades appear; and then a whitish area is seen. Points within the diagram represent different mixtures of color (hue) and different saturations. For example, the midpoint on a straight line connecting pure green and pure white represents a color having a yellowish green hue and a saturation of 50 percent.

17-12. The area inclosed by the triangle B.G.R, as illustrated in figure 89, contains all the hues and saturations that are specified by FCC for color TV. The colors outside the triangle are relatively unimportant since they rarely occur in nature. Excellent color fidelity is therefore attainable in a color TV system that transmits the range of hues and saturations within the FCC chromaticity triangle.

17-13. Because a chromaticity diagram does not include luminance, we need look to figure 90, which illustrates the relative response of the human eye to the various colors in the spectrum.

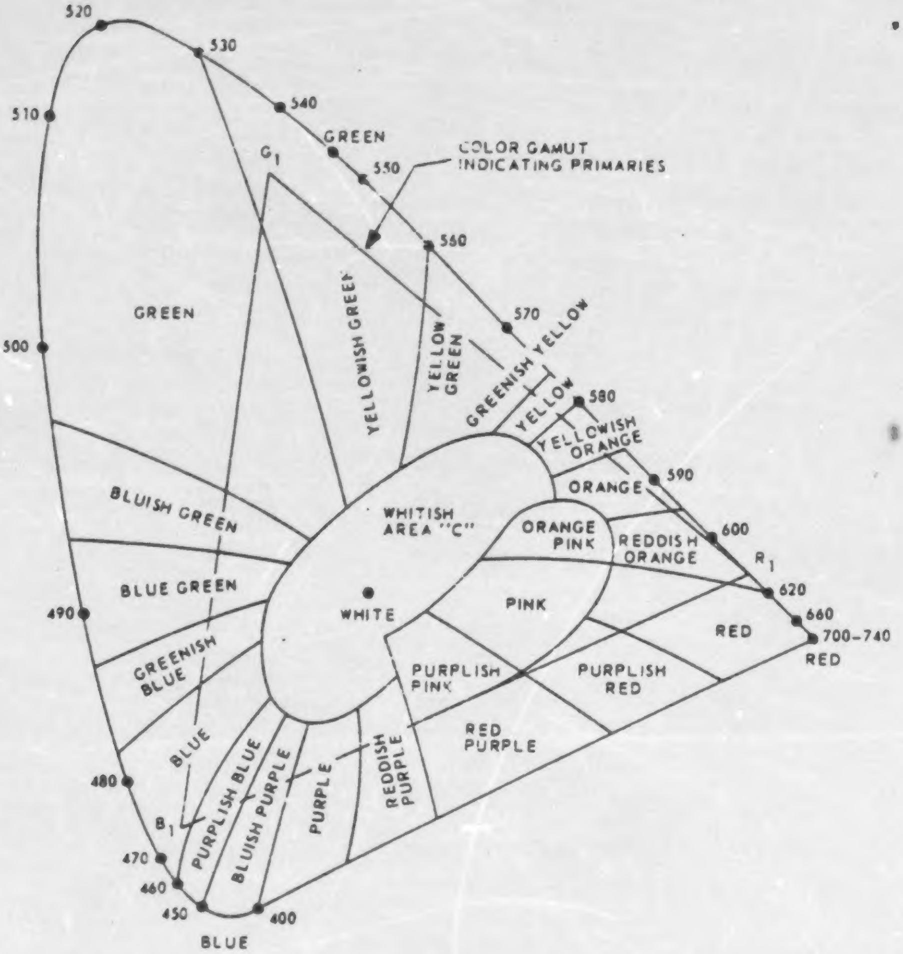

520
530
510
540
GREEN
G$_1$
COLOR GAMUT
INDICATING PRIMARIES
550
560
GREEN
YELLOWISH GREEN
YELLOW GREEN
570
GREENISH YELLOW
500
YELLOW
580
YELLOWISH ORANGE
590
ORANGE
BLUISH GREEN
WHITISH AREA "C"
ORANGE PINK
REDDISH ORANGE
600
R$_1$
620
BLUE GREEN
WHITE
PINK
660
490
700–740
RED
RED
GREENISH BLUE
PURPLISH PINK
PURPLISH RED
RED PURPLE
BLUE
480
REDDISH PURPLE
PURPLE
BLUISH PURPLE
PURPLISH BLUE
B$_1$
470
460
450
400
BLUE

Figure 89. Chromaticity diagram.

Of the three TV primaries, note that green appears the brightest. In white light the proportions of the color primaries sensed by the eye are 59 percent green, 30 percent red, and 11 percent blue. If you keep these color proportions constant while slowly decreasing light intensity, the brightness changes from white through progressively darker shades of gray to black. Therefore, brightness is achromatic even though it contains the three color components.

17-14. Although color has three properties, the eye's ability to perceive them depends upon the size of the image (object or area) being viewed. For relatively large images, the eye sees the full range of hue, saturation, and brightness present. As size decreases, the eye becomes less discerning and partially colorblind. So much so that for very small images, it sees colors as shades of gray from black to white. This is to say, the eye is completely colorblind with regard to fine detail; therefore, only luminance is needed since the eye is incapable of sensing the hue and saturation of very small images. These perceptive characteristics are used to advantage in color TV, as we will point out shortly.

17-15. *Compatibility and bandwidth.* Compatibility is a requirement that must be met for color broadcasting. This means that (1) a color video signal must provide a standard black-and-white (monochrome) signal, (2) chrominance information must be contained within the standard TV bandwidth, and (3) the chrominance signal must not interfere with the monochrome signal. These requirements are met by the National Television System Committee (NTSC) color system. Since the NTSC system is used throughout this country, you need to understand that it is compatible with the standard monochrome system.

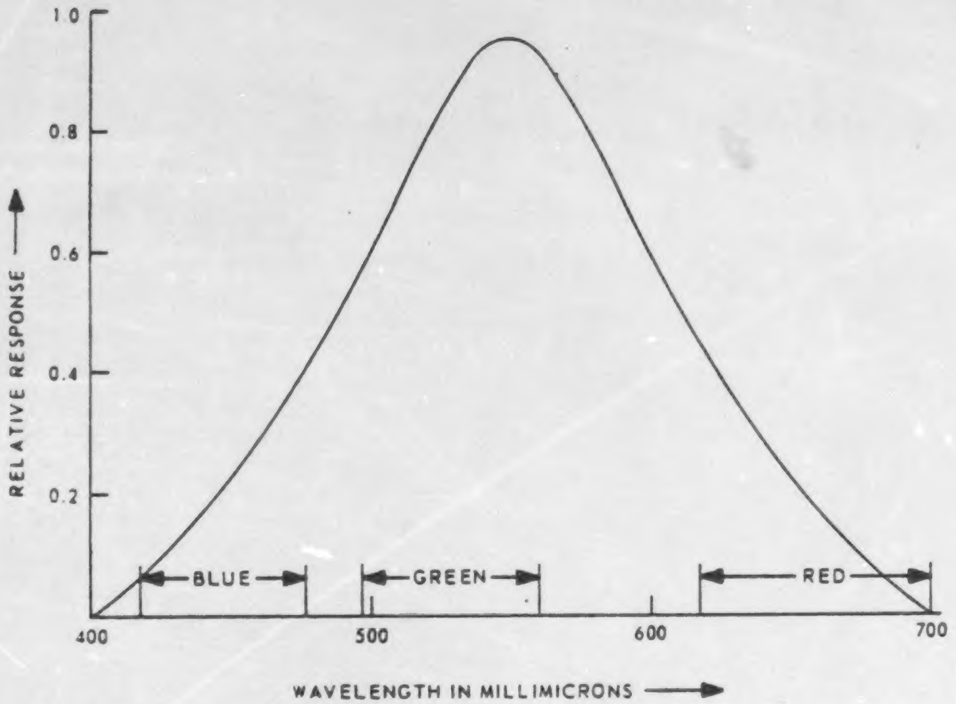


Figure 90. Luminance curve showing sensitivity of human eye.

17-16. The first requirement is met by transmitting a composite black-and-white video signal having practically identical waveform standards for amplitude modulation (AM), synchronization, and blanking as a monochrome system. A spectrum analysis of this signal (see fig. 91) shows that the frequencies constituting it do not occupy the entire band, but occur in clusters near harmonics of 15,750 cps, the scanning line frequency. Such being the case, frequencies constituting the chrominance signal can be distributed between these clusters within the 4.5-mc range without disturbing the black-and-white signal. This is how the NTSC color system satisfies the second and third requirements for compatibility. By modulating an odd harmonic of one-half the line scanning frequency, the chrominance frequencies are placed in the spectrum midway between the clusters of the monochrome frequencies. This principle is called *interleaving*. A frequency of 3.58 mc, which is approximately the 455th harmonic of ½ × 15,750 cps, is used as the color (chrominance) carrier. In a r-f transmission system, it is called a subcarrier since the composite video signal modulates the r-f carrier.

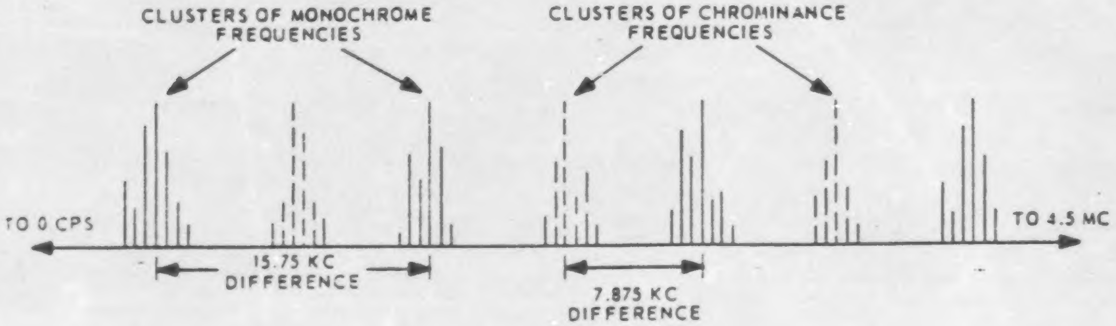

CLUSTERS OF MONOCHROME FREQUENCIES
CLUSTERS OF CHROMINANCE FREQUENCIES
TO 0 CPS
TO 4.5 MC
15.75 KC DIFFERENCE
7.875 KC DIFFERENCE

Figure 91. Interleaving of chrominance frequencies.

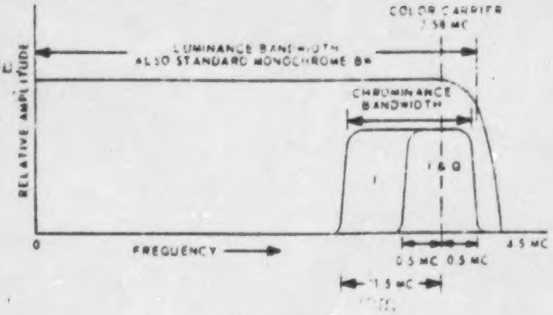


Figure 92. Bandwidths for NTSC color video.

VHF and UHF carrier systems will be covered later in Volume 2.

17-17. In addition to rigid adherence to the FCC monochrome bandwidth requirements, there are bandwidth requirements peculiar to the NTSC color system. The bandwidths assigned to the chrominance frequencies are based on the perceptive characteristics of the human eye described earlier. Video picture information is divided into two parts: (1) luminance which is called the Y or M signal (from here on referred to as Y) and (2) chrominance which consists of components called I and Q signals. The Y signal occupies the same bandwidth as the standard monochrome signal. Large, medium, and very small images are adequately televised within this bandwidth. Because the eye is colorblind for very small images, the Y (luminance) signal is sufficient. Consequently, the chrominance signal is not required and the bandwidth can be reduced considerably for the I and Q components. Both the I and Q signals contain the three primaries, but in different proportions. The hue for the I component ranges from cyan to orange. This range of color was selected for medium size images because it gives adequate color fidelity. Medium size images are televised well within a video range of 1.5 mc; therefore, the I component is assigned this range. Only large images need the Q component, which when combined with the I gives the full color spectrum. A video range of 500 kc (0.5 mc) is ample to convey large image information.

17-18. What has been said thus far concerning bandwidth is illustrated in figure 92. Note that the bandwidth for the luminance signal is the same as that for the standard monochrome signal. Because the chrominance signal is a modulated signal having a 3.58-mc reference, the bandwidth shown extends above and below this frequency. For the I component, the full 1.5-mc range is used to produce the lower sideband, but only a 0.5-mc range is used to produce the upper sideband. By having a vestigial upper sideband, I frequencies are kept within the standard video bandwidth. This is not necessary for the Q component, however, since its full range is only 0.5 mc. An entire upper and lower sideband is therefore used. Observe that both the I and Q components are present over a 0.5-mc video range, thereby providing maximum color for large-size areas; whereas, only the I component is present from 0.5 mc to 1.5 mc, the range in which the full color spectrum is not required for middle size images.

17-19. *Sync.* The waveforms of horizontal and vertical sync pulses for color TV are no different from those for monochrome TV. There are slight frequency differences; however, they are well within the tolerance limits of a monochrome system. For color, the horizontal (line) sync is 15,734 cps instead of 15,750 cps, and the vertical (field) sync is 59.94 cps instead of 60 cps. Besides the horizontal and vertical sync, a 3.58-mc signal sync is used in the NTSC system. This signal would not be needed if the 3.58-mc color carrier were transmitted in the chrominance signal. But it isn't. The color carrier is completely suppressed in the modulation process for two reasons: (1) to reduce beat frequency interference and (2) to attain higher transmitter efficiency. Being absent, the 3.58-mc carrier must be inserted by the local oscillator of a color receiver or monitor. It is extremely important that the local oscillator frequency and the transmitter's 3.58-mc reference frequency are synchronized, because color distortion will result if they are not. Therefore, immediately following each horizontal sync pulse, a burst of the 3.58-mc reference signal is transmitted. This sync is called the *color burst signal*. Note in figure 93 that it is

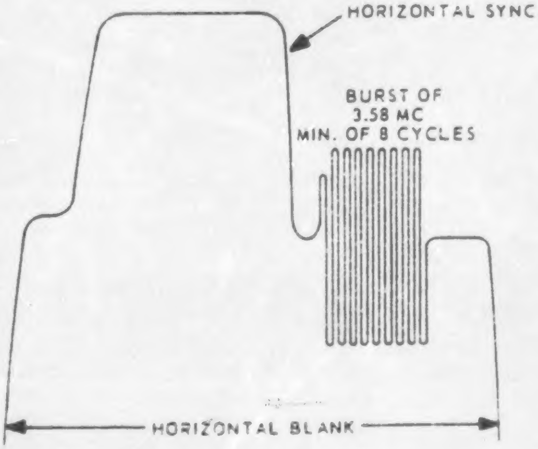


Figure 93. Color burst sync.

placed on the back porch of the horizontal blank pulse.

17-20. *Chrominance circuits.* Having reviewed the compatibility, bandwidth, and sync requirements for color TV, let's identify the additional circuitry needed in an NTSC color camera chain and monitor.

17-21. The color camera chain consists of a color camera, camera control unit, sync generator, processing amplifier, and colorplexer. For distribution and versatility, a switcher and a DA network are used. In the following section we will discuss each of these units in some detail, but we wish here to point out that chrominance information must be handled as well as luminance information. Generally speaking, this necessitates closer tolerances and more complex units. The color camera contains a special optical system, three camera tubes with their associated preamplifiers, and video networks. Consequently, the camera control panel must control three camera tube outputs and their relationships. Because a 3.58-mc sync is required, the color sync generator must provide this frequency and the keying (flag burst) pulse to properly time the 3.58-mc synchronizing signal. Whereas in a monochrome camera chain the camera control unit processes the video, in a color camera chain signal processing plus additional functions are done by a processing amplifier unit. Another unit not found in a monochrome camera chain is, of course, the colorplexer. It performs the functions necessary to produce the composite color video signal. This entails matrixing, filtering, delays, modulation, and mixing to produce the composite color video. Obviously, there are many more functions performed in a color camera chain than there are performed in a monochrome camera chain.

17-22. As in the camera chain, chrominance circuits add appreciably to the complexity and sophistication of color monitors. You should realize, however, that there are many functions which they have in common with the monochrome monitor. The luminance signal is handled in the same manner by both. A color monitor must handle the chrominance signal also. This requires circuits to detect, process, and separate the primary color signals that are needed to drive a color kinescope. Our coverage of color monitors, in the final section of this chapter, will concentrate on these circuits.

18. The Camera Chain

18-1. Figure 94 shows a block diagram of a color camera chain. In this section we will describe the functions performed by each block in the diagram. Particular attention will be given to features that are unique to an NTSC color system.

18-2. **Cameras.** The color camera is much larger than the same type monochrome camera due to the increase of circuitry necessary for the three pickup tubes and the optical system. All live pickup color cameras use three identical pickup tubes with an associated optical light-splitting system to provide simultaneous blue, green, and red signals. With the exception of the three pickup tubes and the associated optical light-splitting system, color cameras are similar to monochrome cameras which you studied in Chapter 4 of this volume. As in monochrome television, two types of pickup cameras are available—one using image orthicon pickup tubes and one using vidicon tubes. These cameras use a light-splitting system like the one shown in figure 95.

18-3. *Optical system.* To develop the color TV signal, the color TV camera must first split the televised scene into three separate light images, blue, green, and red. Figure 95 shows a sketch of an optical system used in a three-tube color TV camera. On the left are the objective

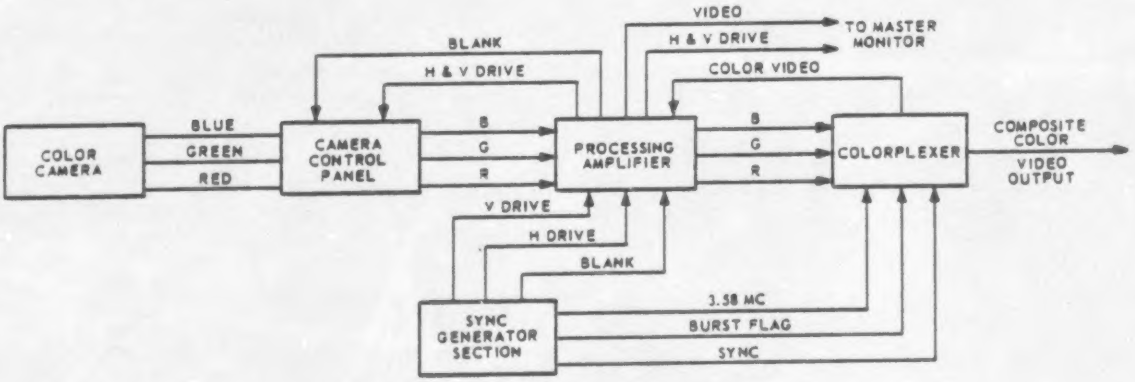


Figure 94. Block diagram of camera chain.

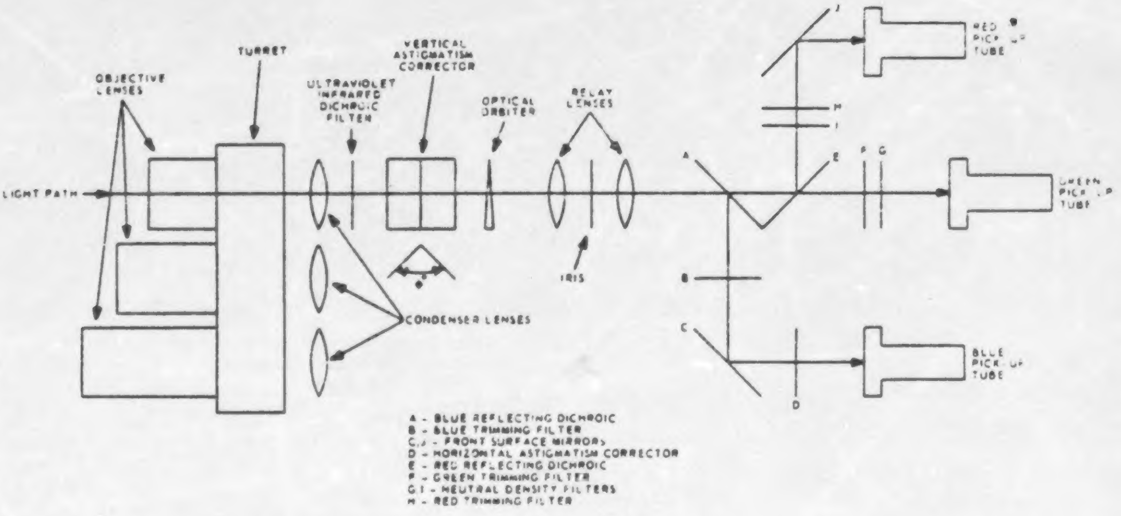

OBJECTIVE LENSES
TURRET
ULTRAVIOLET INFRARED DICHROIC FILTER
VERTICAL ASTIGMATISM CORRECTOR
OPTICAL ORBITER
RELAY LENSES
LIGHT PATH
CONDENSER LENSES
IRIS
RED PICKUP TUBE
GREEN PICKUP TUBE
BLUE PICKUP TUBE
A
B
C
D
E
F
G
H
I
J
A - BLUE REFLECTING DICHROIC
B - BLUE TRIMMING FILTER
C,J - FRONT SURFACE MIRRORS
D - HORIZONTAL ASTIGMATISM CORRECTOR
E - RED REFLECTING DICHROIC
F - GREEN TRIMMING FILTER
G,I - NEUTRAL DENSITY FILTERS
H - RED TRIMMING FILTER

Figure 95. Color camera lens system.

lenses mounted on a rotating turret, which is very similar to the turret used in the monochrome camera. Three types of lenses, wide-angle, normal, and telephoto, are normally mounted on the turret; and the cameras may be equipped with the zoom-type lens. The three lenses on the turret do not split up the light into three primary colors, as only one lens is used at one time. Again referring to figure 95, you see that the light enters one objective lens and follows a path toward the pickup tubes.

18-4. After passing through the selected lens, light passes through the condenser lens. It then passes through the dichroic trimming filter which removes the ultraviolet and infrared portions of the spectrum. The vertical astigmatism compensator then corrects the distortion of optical focus caused by light passing through the dichroic mirrors at an angle. Light then enters the optical orbiter (image orbiter), a rim-driven glass wedge which is mounted in a geared ring driven by a motor through a gear train. The image orbiter is a device which rotates the camera image in a slow, continuous elliptical orbit, undetectable to the TV viewer. Its purpose is to prevent image "burn-in" or "sticking" of the image orthicon pickup tube. Sticking occurs after a camera is held stationary on a high contrast scene for 10 to 30 seconds or more. A negative image remains visible for intervals ranging from a few seconds to several minutes, depending upon the age of the tube and the severity of the burn. Rotation of the optical image falling on the photocathode is a practical way to prevent the image orthicon from sticking. This is accomplished in the color camera by the optical orbiter. The image moves in a circle, and the duration of each orbiting cycle is 1 minute. A DC motor, acting through a gear train, drives the optical wedge mounted in a geared ring. Since the light at this point is common to all three pickup tubes, individual electrical orbiters are not necessary for each tube. Upon leaving the optical orbiter, the light passes through the relay lenses, where the length of the optical path is increased to provide space for the dichroic mirrors and associated elements. Between the relay lenses is the iris, which is used to adjust the amount of light to be passed to the pickup tubes.

18-5. A dichroic mirror is designed to reflect a specific light and pass all others. In figure 95, mirror A will reflect blue light but pass red and green light. The blue light is reflected to the face of a front-surface mirror which reflects the light to the pickup tube designated for blue signal output. The red and green light passes through the blue-reflecting dichroic mirror to red-reflecting dichroic mirror, E. The green light continues through mirror E to the green pickup tube. The red light is reflected by mirror E to front-surface mirror J, where it is reflected to the red pickup tube.

18-6. The three camera tubes are adjusted to have equal output when the televised scene is the RETMA chart. Notice that B, F, and H are blue, green, and red trimming filters. These filters are placed in the light paths to adjust the spectral response of the color camera pickup tube. The spectral response of the combined camera tubes should be equal to that of the monochrome camera. The spectral response in the monochrome camera is very similar to the spectral response of the human eye, as shown in figure 90. Since the dichroic mirrors have rather broad spectral responses, the trimming filters placed in the three light paths are adjusted so that the total or combined response approaches that of the human eye. The trimming filters are adjusted according to light conditions; indoors they are adjusted to artificial light, outdoors they are adjusted to natural light.

18-7. In the red and green light paths are two neutral density filters (G. I. fig. 95). Since the three camera tubes are adjusted to have equal outputs where televising a white or neutral scene, neutral density filters must be placed in the red and green light paths to compensate for the unequal response of the eye to the hues that make up white light. Recall from figure 90 that the eye responds differently to the various colors in white light. The filters reduce the light in the red and green paths to equal the amount in the blue path.

18-8. The additional horizontal astigmatism corrector, D, in the blue light path is used to balance all three light paths astigmatically. Additional correction is not needed in the green and red paths, as each of these colors passes through additional dichroic mirrors.

18-9. *Camera tubes.* Camera pickup tubes used for color production are usually an improved type or design. The most commonly used image orthicon is an improved version of the tube originally designed for monochrome use. Since the color signal is a combination of the output from three tubes, the output from the tubes must be uniform. This requires a precision tube with an output free from spurious signals.

18-10. Many of the changes made to improve the image orthicon tube for color operation are not physically perceptible; however, they are evident in tube performance. Reduction of screen-to-target spacing extends the contrast range and improves the signal-to-noise ratio below the "knee." Closer spacing (from three thousandths to one thousandth of an inch) allows the screen to collect more of the secondary electrons from the target; this eliminates random secondary redistribution of the target electrons and minimizes "ghost" and "halo" effects. The newer tubes are much more sensitive due to the use of an improved photocathode, micromesh screen, and dynode coating and construction.

18-11. You will recall that with the monochrome tube we operate the image orthicon above the "knee." For color operation, however, the image orthicon must be operated at the "knee" to give a more uniform signal free from spurious signals.

18-12. The newer vidicon is also of an improved design; the sensitivity of the mosaic or photosensitive material has been increased. Presently, experiments are being conducted to develop a combination tube which will function much the same as a vidicon but have the pickup sensitivity of an image orthicon.

18-13. **Camera Controls.** Color camera system controls for setup and adjustments are located on both the camera and the camera control panel. Viewfinders mounted on the camera are used as an aid in camera alignment. After setup and adjustment the only controls that are used for operation are those located on the camera control panel.

18-14. *Viewfinder and camera mounted controls.* The controls for adjustment of the camera are arranged at the rear of the camera, whereas focus, brightness, and contrast adjustments for the viewfinder kinescope are located on the viewfinder panel. A series of pushbuttons permits the camera operator to observe a monochrome image of a single channel or any combination of the red, blue, and green channels. These pushbuttons are located on the viewfinder panel.

18-15. Controls to adjust the camera include the blue and red skew controls and Q controls for the three channels. The skew controls are used to adjust to one rectangular shape the blue and red images. The Q controls are linearity adjustments. Also included are conventional height and width controls for individual and overall adjustment of the three channels. The color camera image orthicon has a dynode gain control for each tube; this control is not found on the monochrome camera. These controls are located on the pickup tube chassis.

18-16. There are video preamplifiers for each of the pickup tubes; these are individual units much the same as those used for monochrome equipment. These preamplifiers are different from monochrome because they are adjustable; one stage has a cathode peaking control for adjusting tilt at the low-frequency end of the response curve and another stage has a high peaking adjustment circuit.

18-17. *Control panel.* Mounted on the camera control panel is a group of symmetrically arranged operating controls for each of the three image orthicons. Colored knobs identify the controls with their respective channels. The individual channel controls include horizontal and vertical centering alignment, orthicon focus, multiplier focus, image focus, and image accelerator voltage settings in each color channel.

18-18. The master gain (iris) and master pedestal controls, both of which are located on the camera control panel, serve as the only operating controls once the camera has been aligned. The master gain control operates a selsyn generator which drives a selsyn motor in the camera to control the iris in the optical system. The master pedestal controls the level of pedestal voltage inserted into the signal at the processing amplifier.

18-19. You can readily see by comparison that the controls of a monochrome system and their functons are similar to those in the color system. However, due to recent developments and improvements in tube, component, and circuit design, there may be slight variations in the number and location of controls for color cameras.

18-20. **Processing Amplifier.** Observe in figure 94 that the processing amplifier is connected to the camera control panel, sync generator, and colorplexer. It performs a number of important functions—those accomplished by the camera control unit in a monochrome system plus several others. Its functions can be itemized as follows: video amplification, cable compensation, shading and gamma correction, regeneration of drive pulses and blanking pulses, generation of signals for test purposes, and electronic switching. The networks employed for these functions are essentially video amplifiers, multivibrators, and waveshaping circuits which you have studied. Our coverage will therefore be confined to describing the inputs and outputs from the processing amplifier so you can better understand its purpose in a color system.

18-21. Figure 94 shows that the processing amplifier receives three inputs from the sync generator—vertical (V) drive, horizontal (H) drive, and blanking pulses. Both the H and the V drive input signals separately trigger multivibrators which regenerate the H and V drive pulses. Thus, the pulse widths of the H and V drive outputs are made independent of the original pulse widths supplied by the sync generator. Precision components are used to maintain H and V drive pulse widths within the close tolerances required for the color system. The blank input from the sync generator is amplified and clipped before it is fed out to the camera control panel as a standard blanking signal.

18-22. Note that the Blue (B), Green (G), and Red (R) video signals are received by the processing amplifier via the camera control panel. Just as in a monochrome system, shading corrections must be made. The horizontal and vertical shading generators are driven by the H and V drive pulses. Besides shading corrections, it is necessary to make gamma corrections. Recall that gamma is a factor that indicates the relationship of brightness variations between the original scene and the reproduced image. Because of the inherent nonlinearity in a system (principally the kinescope's characteristics), it is necessary to incorporate gamma correcting amplifiers. These amplifiers are designed to produce nonlinearity which is the inverse of that caused by the rest of the system. When necessary, provision is also made to compensate for attenuation and distortion caused by interconnecting cables. This is generally done with plug-in units, the number used depending upon the lengths of the cables involved. Although we have not designated the B, G, and R signal outputs differently, bear in mind that they are different from the B, G, and R inputs. The outputs are *corrected* video signals. These signals are fed to the colorplexer, which in turn provides another input to the processing amplifier unit. This input is sent to an electronic switcher network, which is used in conjunction with the monitoring facilities. We see in figure 94 that there is a video output to the master monitor. By a switch arrangement, it is possible to monitor the B, G, R, or Y signal separately (monitors will be discussed in the next section). It is also possible to select a composite of the color signals, such as blue-green, or red-blue-green. Moreover, calibration signals can be supplied by the processing amplifier unit to the video output for observation on the master monitor. So you see that the processing amplifier is designed to provide signals for checking pertinent waveforms.

18-23. **Sync Generator.** In Chapter 3, Section 8, you studied the standard monochrome sync generator. Since the NTSC color system is compatible, the sync generator for a standard monochrome system can be used to supply the H and V blanking, drive, and sync signals needed for color. We just pointed out that improvement of these signals (closer pulse width tolerances) is accomplished by the processing amplifier. You know, however, that a 3.58-mc sync (color burst signal) must also be transmitted. Therefore, two additional outputs are shown in figure 94–a 3.58-mc carrier (r-f subcarrier) and a burst flag signal.

18-24. The 3.58-mc (actually 3.579545 mc) signal is obtained from a color frequency standard generator. This generator is a crystal-controlled oscillator which is kept in a temperature-regulated oven. The oscillator generates a highly stable signal (about ±3 cps per mc) for the colorplexer and countdown circuits of a standard monochrome sync generator. When the

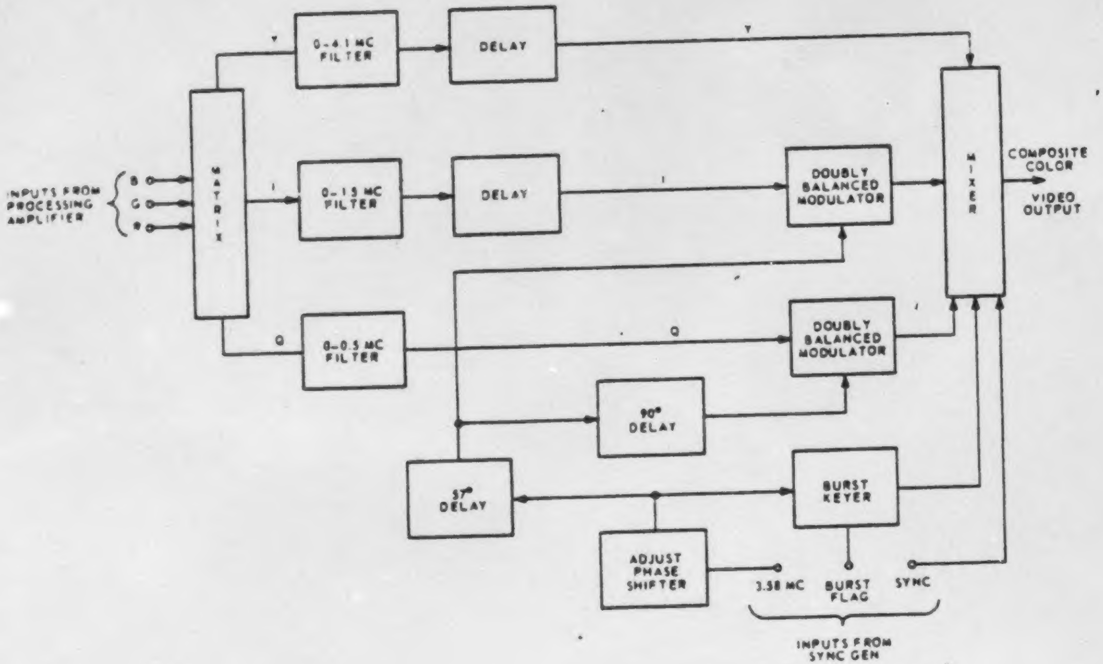


Figure 96. Block diagram of colorplexer.

31.4685-kc (instead of 31.5 kc) is counted down, you get the slightly different line and field frequencies (15,734 cps and 59.94 cps respectively).

18-25. A burst flag generator develops a series of rectangular pulses at the horizontal line frequency. These pulses are timed to place the 3.58-mc burst on the back porch of the horizontal blanking pulse. Because this is done in the colorplexer by a gating (keying) circuit, the burst flag is sent from the sync generator unit to the colorplexer, as shown in figure 94. It stands to reason that the burst flag signal must be precisely timed and locked in by the horizontal line frequency of the color system. Furthermore, the width of the burst flag pulse permit at least eight complete cycles (see fig. 93) of 3.58 mc.

18-26. **Colorplexer.** The functions of filtering, phasing, modulating, and mixing, which occur in the colorplexer unit, are vital to the operation of an NTSC color system. It is therefore essential that you understand these various functions. To identify and relate them, we can use to advantage the diagram of a colorplexer shown in figure 96. Note that inputs are received from the processing amplifier and the sync generator. The colorplexer modifies and combines these inputs to produce a composite color video output. This output signal contains all the frequencies necessary to transmit luminance, color, sync, and blanking information to a monitor for a color display. Beginning with the B, G, and R signal inputs, we will investigate the manner in which the composite color video output is obtained. The facts discussed concerning compatibility and color perception underlie the design and operation of this unit. We suggest, therefore, that you review these facts if you have difficulty following our explanation. We will not attempt to delve into the mathematical aspects of color signal formation since this is not necessary to convey the principles and processes involved. A detailed treatment of this subject can be found in TO 31S4–1–1A and numerous commercial publications.

18-27. *Matrix and filter sections.* The three inputs from the processing amplifier are the primary color signals that originate at the color camera. These signals (B, G, and R) are applied to the matrix section of the colorplexer (see fig. 96). This section combines the primary color signals to produce the luminance (Y) signal and two color signals (I and Q). This is done by resistance networks and phase inverters. In figure 97 we have illustrated an arrangement whereby the proper proportions and polarities of the primary color signals are obtained to produce the desired Y, I, and Q outputs. For simplicity, let's assume that the color camera is picking up pure white light. In this case, the B, G, and R

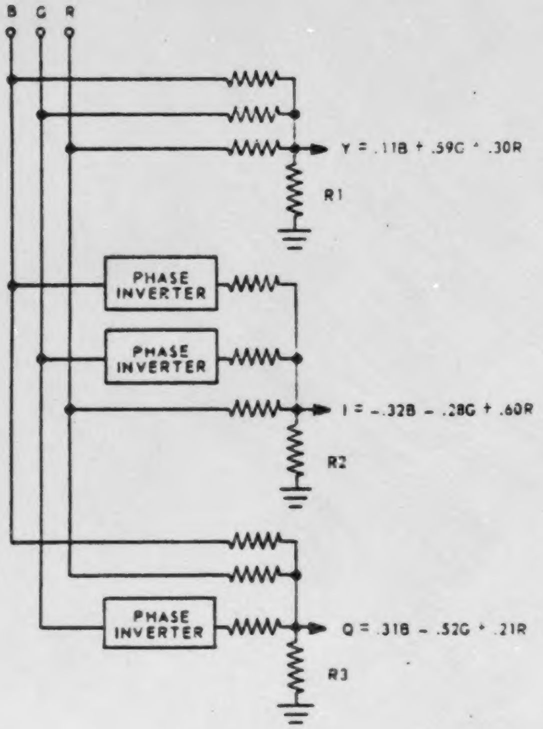


Figure 97. Colorplexer matrix circuits.

signal inputs should all be of equal amplitude. We know, however, that because of the perceptive characteristics of the human eye, white is not seen unless the proportions of the primary hues are 11 percent blue, 59 percent green, and 30 percent red. Since Y is the white signal, it must have these proportions; thus, Y = .11B + .59G + .30R as shown. Note how this is accomplished by voltage divider circuits. The resistors connected to the B, G, and R lines differ in value, of course; so the proper amount of each signal is developed across the common output resistor R1. Similarly, the I and Q signals are developed across R2 and R3, respectively. A difference is that the I signal has two negative components and the Q signal has one. Consequently, phase inverters are placed in the B and G divider circuits of the I matrix, and in the G divider circuit of the Q matrix. As you can see, the color signals are I = −.32B − .28G + .60R and Q = .31B − .52G + .21R. Both the I and Q signals are zero if the camera is picking up pure white light as we assumed. For example, suppose the B, G, and R inputs to the matrix are each 1v (equal for white light). Substituting 1v for B, G, and R in the expression for I and Q, we get I = 0 and Q = 0. However, if any colored light is being picked up, there will be an I or Q signal or both.

18-28. The I color signal is obtained for orangish hues, and the Q color signal is obtained for bluish-red (magenta) hues. We should mention here that I and Q can have a negative polarity. For bluish-green (cyan) hues, a −I signal is obtained; for yellowish-green hues, a −Q signal is obtained. Figure 98 shows the values and polarities for I and Q signals of fully saturated primary and secondary colors.

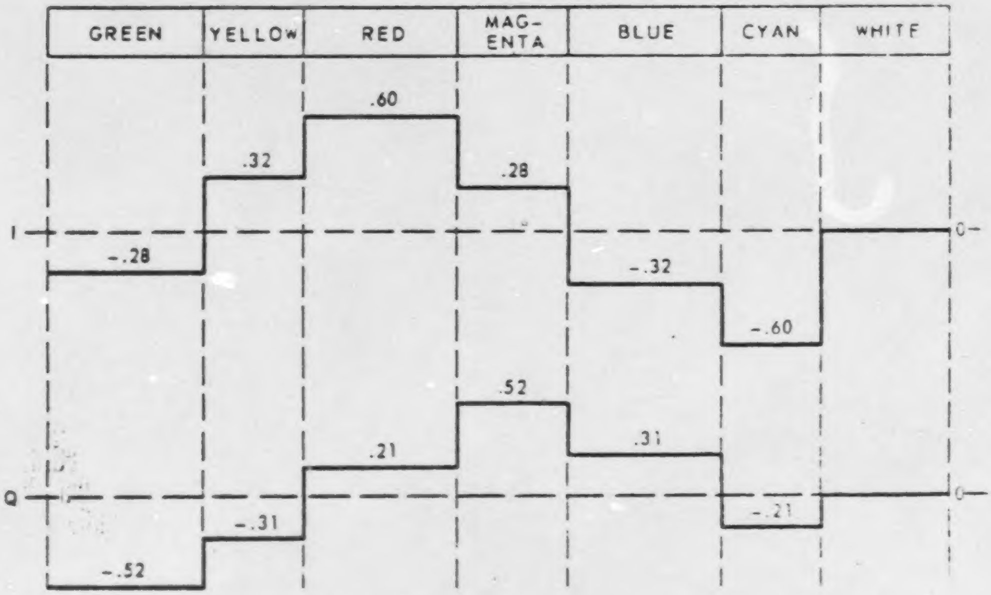


Figure 98. I and Q signals for primary and secondary colors.

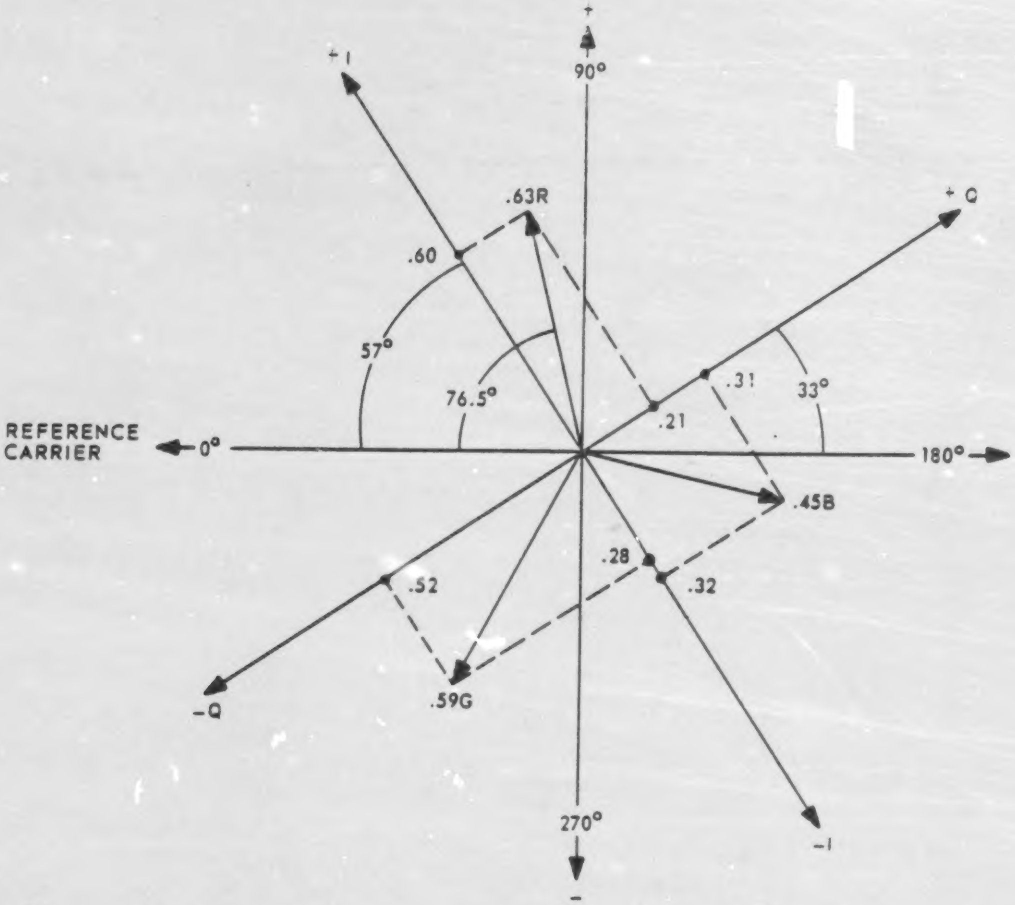


Figure 100. Vector diagram of color signals.

lationships of the inputs. Therefore, the I modulator's output contains the I color information as sideband frequencies. Likewise, the Q modulator's output contains the Q color information as sideband frequencies. Bear in mind, however, that modulated I and Q outputs are 90° out of phase with each other.

18-32. *Mixer section.* Refer again to figure 96 and note the inputs to the mixer. This section combines the luminance, color, and sync information to form the composite color video output that is transmitted.

18-33. Figure 101 illustrates the signal development for the indicated color elements. High saturations of red, blue, green, and yellow are considered to be 100-percent saturated colors. Those saturations of green and yellow are considered as 50 percent saturated colors. The shaded areas of the three camera signal output waveforms (B, C, and D) represent the white component of the 50 percent saturated green and yellow.

18-34. By applying the formula $Y = .30R + .11B + .59G$ to all three camera tube output signals for any one color, the Y signal waveform at E will be developed. When applied to a black-and-white receiver, this video waveform will represent the brightness charactristic of the color elements illustrated.

18-35. The I signal is developed by applying the formula $I = .60R + .32B - .28G$ to the three camera signal output waveforms for any color. Similarly, the Q signal for the illustrated color elements can be developed by application of the formula, $Q = .21R + .31B - .52G$. The I and Q signals, combined in quadrature, form the chrominance signal; the signal phases and amplitudes for the illustrated colors are indicated at H. The high saturation of green, for example, has a chrominance signal amplitude of .59 at a certain phase. The amplitude and phase are determined by the amplitudes of −I and −Q produced for the green.

18-29. From the matrix section, the Y, I, and Q signals go to a filter section. Recall that the bandwidth requirement is different for each of these signals (refer to fig. 92). We explained earlier that the bandwidths are based on the eye's color-detecting characteristics. As the image becomes smaller, the eye fails to detect color accurately until color is not perceived at all. Thus, color signals can have comparatively narrow video bandwidths; the Q signal having the narrowest, from 0 to 500 kc. Since the Q signal is delayed most by its filter, it is necessary to insert an additional delay following the I filter and even more delay following the Y filter (see fig. 96). It is important that these delays be correct. Otherwise, the signal relationships will not be proper and color distortion results.

18-30. *Modulator section.* Observe in figure 96 that the I signal is fed into a doubly balanced modulator which has a 3.58-mc input. The same is true for the Q signal. Note, however, that the 3.58-mc input to the Q channel is delayed 90° more than the 3.58-mc input to the I channel. Note also that the 3.58-mc is received, via an adjustable phase shifter and 57° delay, from the sync generator. The adjustable phase shifter circuit makes it possible to align the 3.58-mc input to the standard reference, which is shown in figure 99 as 0°. This figure illustrates the phase relationships of the I and Q signals to the color carrier and to each other. The outline of the chromaticity diagram and the FCC color triangle are shown so that you can see the range of hues and saturations that are encompassed by the I and Q signals. A more complete vector diagram is shown in figure 100. This diagram can be correlated with figure 98 and also with figure 99.

18-31. We mentioned previously that the I and Q signals are each sent to a doubly balanced modulator. This type of modulator develops an amplitude-modulated output that contains neither of the input signals. The output does nonetheless contain the sideband frequencies which depend upon the amplitude and phase re-

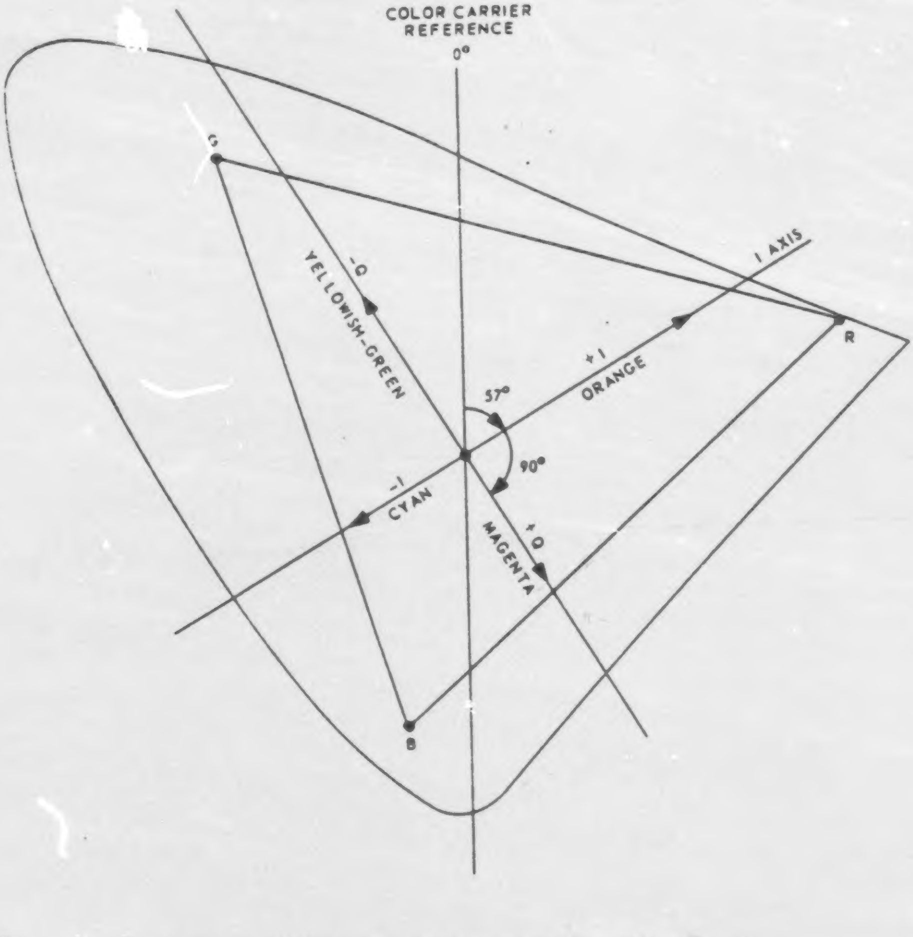


Figure 99. Position of I and Q vectors on chromaticity diagram.

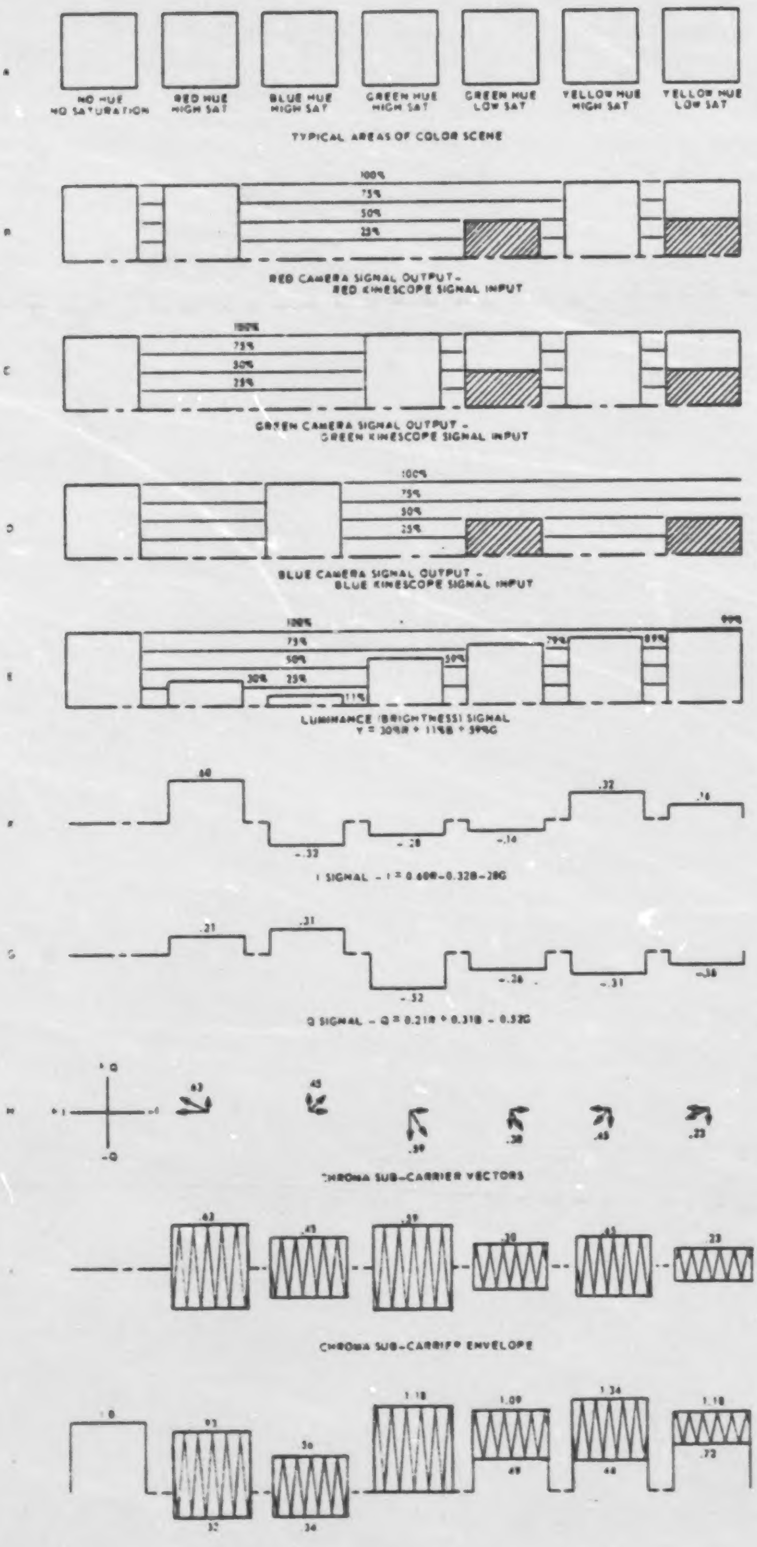

A
NO HUE NO SATURATION
RED HUE HIGH SAT
BLUE HUE HIGH SAT
GREEN HUE HIGH SAT
GREEN HUE LOW SAT
YELLOW HUE HIGH SAT
YELLOW HUE LOW SAT
TYPICAL AREAS OF COLOR SCENE
B
100%
75%
50%
25%
RED CAMERA SIGNAL OUTPUT - RED KINESCOPE SIGNAL INPUT
C
100%
75%
50%
25%
GREEN CAMERA SIGNAL OUTPUT - GREEN KINESCOPE SIGNAL INPUT
D
100%
75%
50%
25%
BLUE CAMERA SIGNAL OUTPUT - BLUE KINESCOPE SIGNAL INPUT
E
100%
75%
50%
30%
25%
11%
59%
70%
89%
99%
LUMINANCE (BRIGHTNESS) SIGNAL
Y = 30%R + 11%B + 59%G
F
.60
-.32
-.28
-.14
.32
.16
I SIGNAL - I = 0.60R-0.32B-28G
G
.21
.31
-.52
-.26
-.31
-.36
Q SIGNAL - Q = 0.21R + 0.31B - 0.52G
H
+Q
+I
-I
-Q
.63
.45
.59
.38
.45
.23
CHROMA SUB-CARRIER VECTORS
I
.63
.45
.59
.38
.45
.23
CHROMA SUB-CARRIER ENVELOPE
1.0
.93
.30
.32
.34
1.18
1.09
.49
1.34
.44
1.18
.72

Figure 101. Evolution of composite color signals.

18-36. Note that the pale green chrominance subcarrier vector has not changed in phase from the highly saturated green, but is merely reduced in amplitude in order to convey the effect of reduced saturation. Comparison of the chrominance signal envelopes for the two saturations of green at I show the amplitude difference due to saturation change. When combined with the brightness signal at J, however, the two composite signal waveforms have little total difference in amplitude for the two greens, but the brightness component of the low saturation of green is greater than that for high saturation of the same color. Note that the chrominance signal changes phase as hue changes, and amplitude varies as saturation varies. As chrominance signal amplitude is reduced for the same hue, the corresponding brightness signal will increase.

18-37. Figure 102 indicates the video modulation for one horizontal scanning line containing fully saturated primary and secondary color bars. The figures at the left of the chart indicate percentages of modulation. The brightness signal for each bar is the a-c axis of each chrominance signal, forming the stairstep pattern from black to white. The video swing from black to white is shown at its maximum tolerance, with white at 10-percent modulation. This provides a contrast range from 70-percent modulation to 10-percent modulation, or 60 percent of the total modulation envelope. Black, then, represents 0 percent of this 60-percent range. The brightness signal for the colors, from left to right, represents the following percentages of this 60-percent range of contrast: blue, 11 percent; red, 30 percent; magenta, 41 percent; green, 59 percent; cyan, 70 percent; yellow, 89 percent; white 100 percent. The green, cyan, and yellow chrominance signals overshoot zero modulation, with yellow representing maximum modulation overshoot. Since fully saturated colors are rarely telecast, however this condition is unlikely to occur.

18-38. The inputs from the sync generator are added in the mixer section. Figure 102 shows the presence of the horizontal blank, horizontal sync, and color sync burst. Remember that the sync signal input also includes the pulses for vercal blank and sync. These pulses have the same waveforms as those for the standard monochrome signal. The horizontal sync pulses occurring dur-

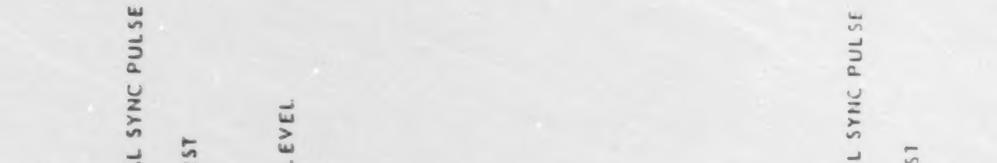
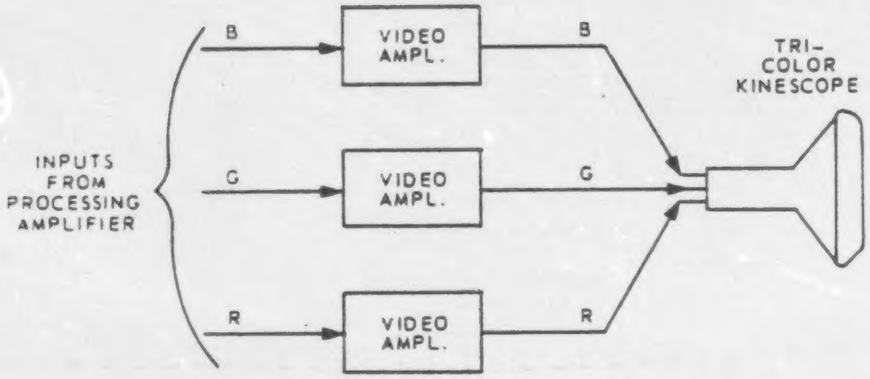
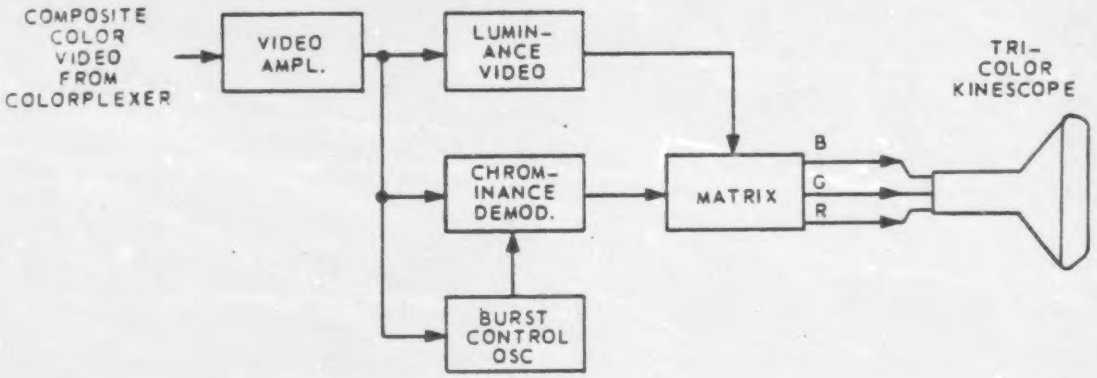


Figure 102. Video modulation for one horizontal scanning line.


B
VIDEO AMPL.
B
TRI-COLOR KINESCOPE
INPUTS FROM PROCESSING AMPLIFIER
G
VIDEO AMPL.
G
R
VIDEO AMPL.
R

A. THREE-INPUT COLOR MONITOR


COMPOSITE COLOR VIDEO FROM COLORPLEXER
VIDEO AMPL.
LUMIN-ANCE VIDEO
TRI-COLOR KINESCOPE
CHROM-INANCE DEMOD.
MATRIX
B
G
R
BURST CONTROL OSC

B. SINGLE-INPUT COLOR MONITOR

Figure 103. Diagrams showing the video channels of color monitors.

ing vertical blanking time will each be followed by a color sync burst. This, of course, insures color synchronization before the vertical blank terminates and the picture begins.

19. Color Monitors

19-1. Color monitoring equipment can be divided into two classes: (a) three-input monitors for viewing the color signals as they leave the camera chain and (b) single-input monitors for viewing the composite color signal from the colorplexer or, in the case of closed-circuit systems, for use as receivers at remote points. Figure 103.A. is a simplified block diagram of a three-input monitor. As is apparent from the block diagram, these monitors consist of three identical video amplifiers (one for each of the red, green, and blue channels). Of course, deflection and convergence circuitry, a tricolor kinescope, and a power supply are used. This type is generally considered as test equipment. Figure 103.B. is the simplified block diagram of a typical single-input color monitor of the type generally used as remote receivers in closed-circuit systems. This type of monitor is designed for continuous operation and uses circuits that are adaptable as closed-circuit system receivers where severe operating conditions are a factor.

19-2. Figure 103 does not show circuits or features common to a monochrome monitor. Such functions as sync separation, scanning, and d-c restoration are accomplished in the same ways for color monitors as for monochrome types. The three-input color monitor amounts to three video channels, one for each primary color signal. The single input monitor, however, incorporates a number of features that are unique. We will therefore give our attention to this latter type monitor. Moreover, we will describe the demodulation and matrixing method that is employed to attain maximum color fidelity in a compatible system (see fig. 104).

19-3. **Luminance Section.** Although the luminance section corresponds to the video section of a monochrome monitor, there is a difference that is shown in figure 104. The Y delay unit is placed in this section so that the luminance signal will have the proper time relationship with the chrominance signal when it arrives at the matrix section. The Y delay must be equal to the delay caused by the chrominance bandpass filter in the demodulation section. This is important since, as we mentioned earlier, incorrect time relationships will cause color distortion.

19-4. Preceding the second video amplifier is a brightness control (not shown), which is used to adjust the d-c reference and thus the overall picture luminance. A contrast control is located in the video output stage just as in a monochrome monitor.

19-5. **Burst Control Oscillator Section.** Before the chrominance signals can be detected, it's necessary to reinsert the 3.58-mc color reference signals. A 3.58-mc signal is generated in the burst control oscillator section by an afc crystal oscillator. Since the locally generated 3.58-mc signal has to be synchronized to the transmitter's color carrier, let's refer to figure 104 and discuss how this is done.

19-6. The input to the burst amplifier comes from the first video amplifier. Observe that there is another input to this section which goes to a keyer circuit. The keyer is triggered by a pulse from the horizontal output stage. Such an arrangement activates the burst amplifier so that it pases the color burst sync to the phase detector. The other input to the phase detector is supplied by the local 3.58-mc oscillator. As you know, the phase detector produces a d-c potential (error voltage) if the inputs differ in phase. The error voltage is applied to a reactance control circuit (such as a reactance tube amplifier or varicap semiconductor diode), which regulates the oscillator frequency. Thus, the 3.58-mc oscillator output is kept in phase with the 3.58-mc color burst sync signal.

19-7. To establish the proper phase relationships for demodulating the I and Q signals, the 3.58-mc signal is delayed 90° before reaching the Q demodulator. We will discuss shortly why

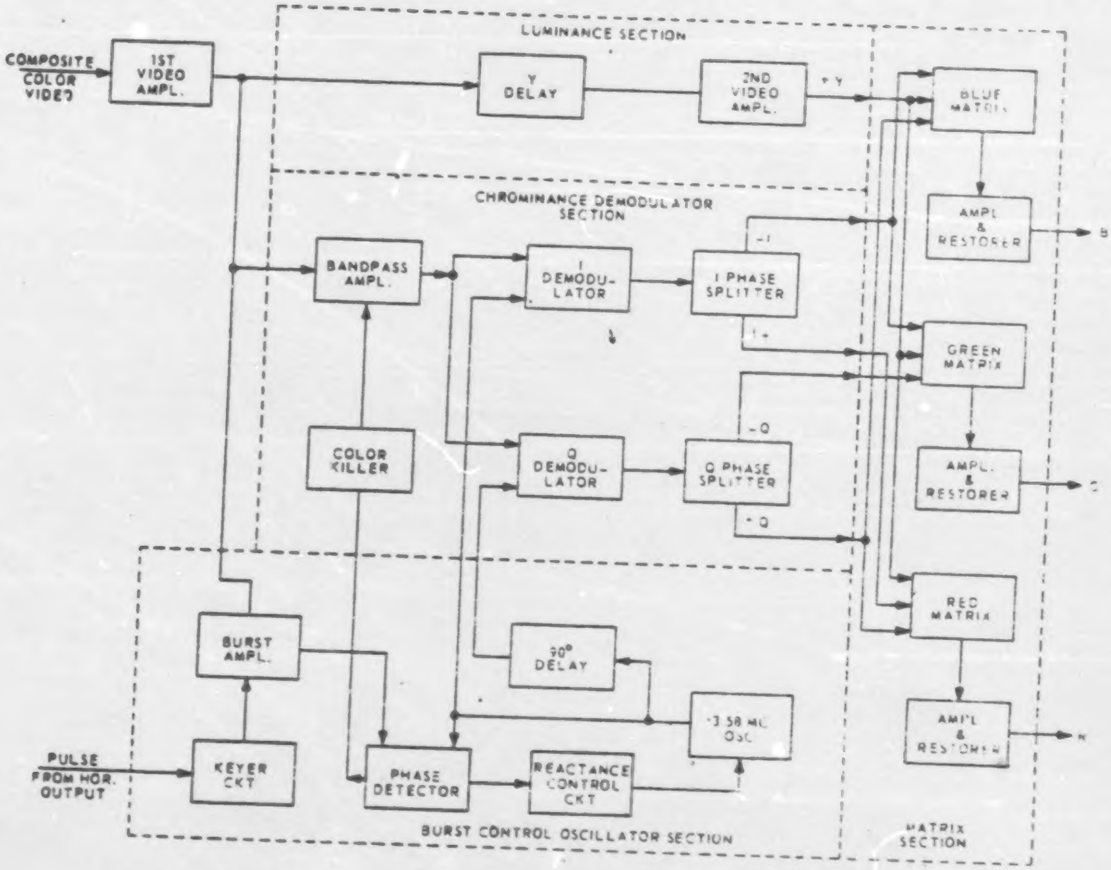

LUMINANCE SECTION
COMPOSITE COLOR VIDEO
1ST VIDEO AMPL.
Y DELAY
2ND VIDEO AMPL.
+Y
BLUE MATRIX
AMPL & RESTORER
B
CHROMINANCE DEMODULATOR SECTION
BANDPASS AMPL.
I DEMODULATOR
I PHASE SPLITTER
-I
I+
GREEN MATRIX
-Q
COLOR KILLER
Q DEMODULATOR
Q PHASE SPLITTER
+Q
AMPL. & RESTORER
G
RED MATRIX
BURST AMPL.
90° DELAY
3.58 MC OSC
AMPL & RESTORER
R
PULSE FROM HOR. OUTPUT
KEYER CKT
PHASE DETECTOR
REACTANCE CONTROL CKT
BURST CONTROL OSCILLATOR SECTION
MATRIX SECTION

Figure 104. Basic units comprising the sections of a color monitor.

this makes it possible to detect the I and Q signals separately.

19-8. Another output from this section is derived from the phase detector and applied to the color killer. Like the error voltage, this output is a d-c potential. It is used to effectively block the video input to the chrominance demodulator section.

19-9. **Chrominance Demodulator Section.** Referring to figure 104, you see that the video input to the chrominance demodulators goes first to the bandpass amplifier. Another input to this amplifier comes from the color killer. The color killer is nothing more than an amplifier that gates the bandpass amplifier when a color video signal is received. On the other hand, the color killer biases the bandpass amplifier to cut off when a monochrome signal is received. The operation of the color killer is dependent upon the d-c potential developed by the phase detector. If a color video is present, there is a color burst sync signal applied to the phase detector, and a d-c output voltage to the color killer is produced. Thus, the color killer only gates the bandpass amplifier when color burst sync is detected. Since a monochrome video signal does not have the color burst sync, the burst is not detected and the color killer cuts off the bandpass amplifier. Simply stated, the color killer kills color when a monochrome signal is received. It prevents color noise from appearing in the black-and-white display.

19-10. For a color signal input, the bandpass amplifier filters and boosts the gain of the chrominance signal which is sent to the I and Q demodulators. These are synchronous demodulators. This type of demodulator is phase selective. It functions much like an electronic switch, detecting the amplitude of one input at the peak of the other input. For example, the I demodulator detects the amplitude of the input chrominance signal each time the input 3.58-mc signal reaches its peak. Since the 3.58-mc signal is in phase with the 3.58-mc reference color carrier, this demodulator detects the amplitude of only the I (in phase) component. In other words, the 3.58-mc carrier is reinserted so that only the I color information is detected. To obtain the Q color signal, it is necessary to reinsert the 3.58-mc signal in quadrature (90° out of phase) with the reference signal. In figure 104, note that the 3.58-mc input is delayed 90° before reaching the Q demodulator. Consequently, the Q demodulator detects the amplitude of the Q (quadrature) component of the chrominance signal. By this technique, it is therefore possible to extract separately the I and Q color information from the chrominance signal.

19-11. The outputs of both the I and Q demodulators are sent to phase splitter amplifiers. This is done because +I and −I as well as +Q and −Q signals are needed to develop the primary B, G, and R signals within the matrix section.

19-12. **Matrix Section.** The matrix section combines the inputs from the chrominance demodulator section (+I, −I, +Q, and −Q signals) with the Y signals from the luminance section in the proportions required to produce B, G, and R signals. Figure 105 illustrates the resistance network that can be employed to combine the prescribed amount of each input. Note in figure 104 that the −I (cyan) signal is applied to the blue matrix and the green matrix, whereas the +I (orange) signal is applied to the red matrix. Also, the −Q (yellowish-green) signal is applied to the green matrix, whereas the +Q (magenta) signal is applied to the blue matrix and the red matrix. The algebraic expressions given in figure 105 for the B, G, and R signals specify the polarities and amounts of the Y, I, and Q signals that comprise the output of each matrix.

19-13. Obviously, the resistance matrix networks are similar to those described when we covered the colorplexer. It should be pointed out, however, that the B and G outputs are made adjustable. This is done so that these outputs

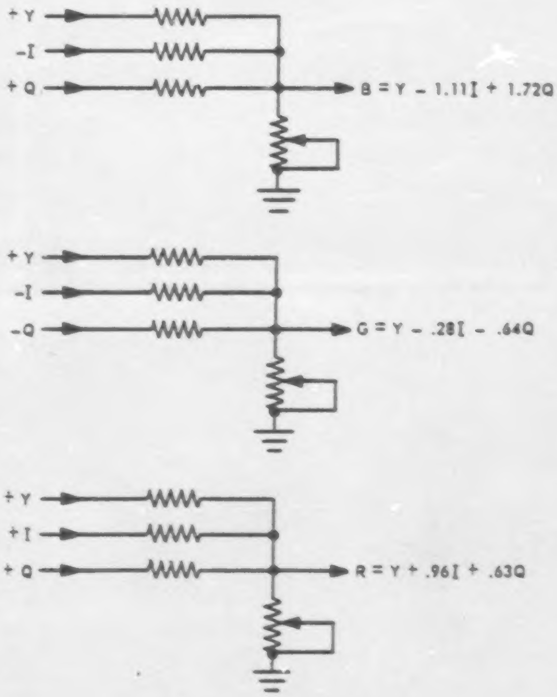


Figure 105. Matrix circuits of color monitor.

can be adjusted to compensate for the luminance differences of the three phosphors in the tricolor kinescope. Since the red phosphor produces the lowest luminance, the red output is ordinarily the fixed reference to which the blue and green outputs are adjusted. This is commonly referred to as the temperature adjustment. Color temperature describes the color quality of light. The "hotter" the color temperature, the whiter the light; the "colder" the color temperature, the yellower the light. As you would expect, the adjustments are made to produce hot light (white as possible) for a white test signal. More will be said about these adjustments later.

19-14. The output from each matrix is amplified to the level needed to drive the tricolor kinescope. D-c restoration is accomplished separately for the B, G, and R signal outputs since they differ when color video is received. The amplifiers and d-c restorers are shown in figure 104 to be units within the matrix section. The outputs from this section are coupled directly to the grids of the tricolor kinescope.

19-15. **Tricolor Kinescope.** The principal parts of the tricolor kinescope are illustrated in figure 106. In the same figure there is an enlarged view of the phosphor dot viewing screen, the shadow mask, and the three-electron gun assembly. This is inclosed by the glass envelope and external shield. When you know the tricolor kinescope construction, you will understand why alignment and adjustment of the three beams is critical.

19-16. *Phosphor dot viewing screen.* The phosphor dot viewing screen will be referred to from here on as the color screen. Amoung the fundamental distinctions between the color tube and the monochrome tube is the difference in phosphor materials. In monochrome a uniform phosphor coating is used; however, the color screen (see fig. 106) is composed of an orderly array of small closely spaced phosphor dots. These dots are arranged in triangular groups, or trios, accurately deposited in interlaced positions on a glass surface. Each trio of dots represents the three primary colors—blue, green, and red. Although the color dots are separate, they are close enough to meet resolution requirements by glowing their respective colors when bombarded by electrons. The brightness of each dot depends on the strength of the electron beam striking that dot.

19-17. *Shadow mask.* The shadow mask (see fig. 106) is a thin metal plate of super-nickel alloy located between the phosphor dot screen and the electron gun assembly. It has approximately the same curvature as the color screen; the monochrome tube does not have a comparable element. The shadow mask has

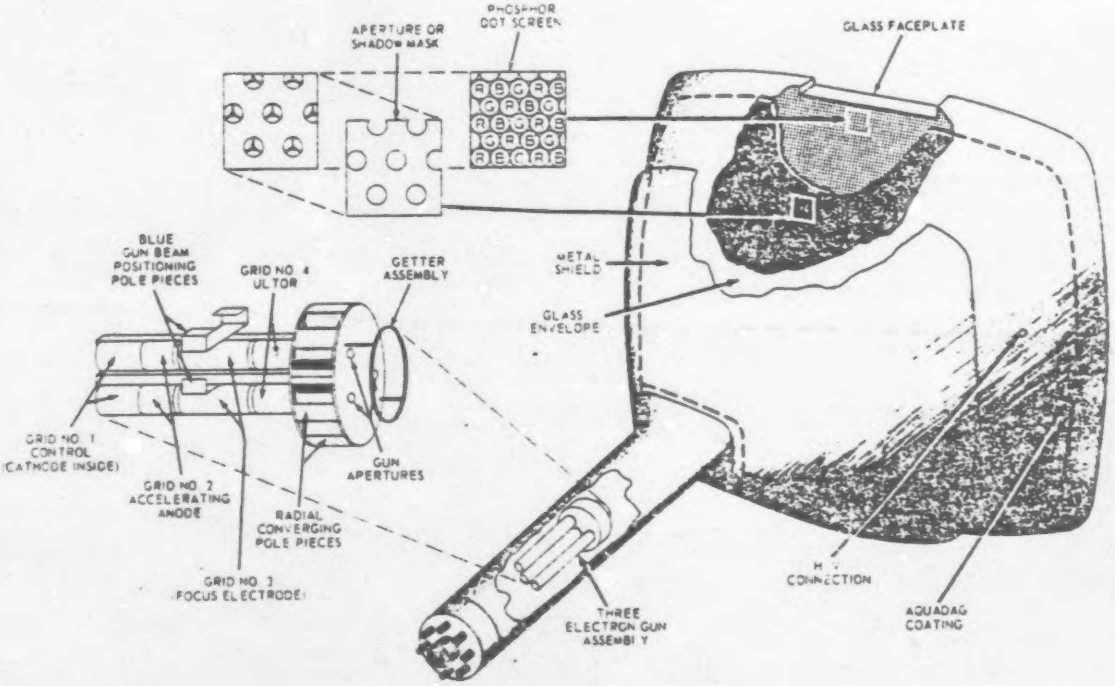

APERTURE OR SHADOW MASK
PHOSPHOR DOT SCREEN
GLASS FACEPLATE
R B G R B
G R B G
R B G R B
G R B G
R B G R B
BLUE GUN BEAM POSITIONING POLE PIECES
GRID NO. 4 ULTOR
GETTER ASSEMBLY
METAL SHIELD
GLASS ENVELOPE
GRID NO. 1 CONTROL (CATHODE INSIDE)
GRID NO. 2 ACCELERATING ANODE
GUN APERTURES
RADIAL CONVERGING POLE PIECES
GRID NO. 3 (FOCUS ELECTRODE)
H. V. CONNECTION
THREE ELECTRON GUN ASSEMBLY
AQUADAG COATING

Figure 106. Tricolor kinescope.

several thousand holes, one for each trio of phosphor dots. These holes are spaced and the hole edges are beveled so that an equal hole is presented to the beam for any angle of beam deflection. Thus, the shadow mask provides color separation by shadowing two of the three dots from two of the three electron beams while exposing the proper dot to bombardment by the correct beam. Therefore, three beams from the three guns converge at the hole in the mask, the beams pass through the hole, diverge, and strike the respective red, green, and blue phosphor dots.

19-18. *Electron gun.* The three-gun assembly, shown in figure 106, is made as one unit and is mounted in the neck of the picture tube. The three electron guns are approximately parallel to each other with a very slight tilt toward the central axis of the tube. The guns are 120° apart and are so small in diameter that the slight tilt causes the three beams to converge at the shadow mask. Some static convergence correction will be necessary for final adjustment.

19-19. Each of the three guns consists of a filament, a cathode, control grid, accelerator grid, focusing anode, and ultor anode. The ultor is the electrode in the gun to which is applied the highest voltage prior to deflection. The highest voltage in the tube is applied to the aquadog coating.

19-20. *Glass envelope and external shield.* The glass envelope (see fig. 106) of the color kinescope is the same as for the monochrome, with the possible exception of shape. The shape of the color tube is changed to accommodate the shadow mask and the three electron gun assembly. This means the front is extended slightly for the shadow mask, and the neck of the tube is larger in diameter for the electron gun assembly. The neck of the color tube is longer to accommodate the accessories which include the convergence assembly, blue lateral magnet, purifying magnet, color equalizer assembly, and deflecting yoke.

19-21. The metal shield placed around the bell portion of the tube shields the electron beam from stray magnetic fields. In some monitors that have metal cabinets, the shield is not necessary. In the early versions of this tube, the shield was an internal part of the tube. This improvement over the early models is indicative of the trend in refinements of color kinescopes; doubtless, there will be many more.

19-22. **Maintenance Requirements.** The maintenance requirements for color monitors are necessarily more involved than those of monochrome monitors. Alignment and adjustment procedures are provided by the manufacturer of a specific color set. Because of the similarities in the basic design of monochrome and color TV monitors, adjustments such as height, width, linearity, etc., are practically the same. These adjustments were discussed in Chapter 5; therefore, we will consider only important adjustments peculiar to the color monitor in the following paragraphs.

19-23. Since equipment design varies, we will cover only those functions common to color TV monitors in general. For a more extensive coverage of this area, you can refer to TO 31-1-141.

19-24. *Convergence.* Two types of control, static and dynamic, are developed in the convergence circuits of a color TV monitor. Static convergance is a steady control. It is accomplished with a d-c voltage to cause convergence in the center portion of the display. By contrast, dynamic convergence is a varying control. It is accomplished with a parabolic voltage which primarily affects the outer edges of the display. The combination of these two control voltages is used to align each electron beam with its respective series of phosphor dots. When all three electron beams are properly aligned, a white trace should be produced on the face of the kinescope.

19-25. A simple observation can be made to determine whether static and dynamic convergence adjustments are proper. With video information applied to the monitor, examine the edges of the objects. If you can distinguish one or more definite colors, convergence needs adjustment.

19-26. *Purity adjustments.* Purity describes the accuracy with which an individual electron beam strikes its own series of phosphor dots. When an electron beam overlaps its dots and partially strikes the dots of another color, hues of colors are noticeable. An examination of the outer edges of the kinescope will divulge any color impurities. Purity adjustments will be necessary if color hues are apparent.

19-27. *Temperature adjustments.* Temperature denotes the correct combination and intensity of colors from the matrix system to produce a white balance, hot light. Deflects in temperature adjustment can be readily detected on the face of the kinescope. By rotating the brightness control through its full range, determine if the background changes to any color hue or range of hues. Should the background change, temperature adjustments will be necessary

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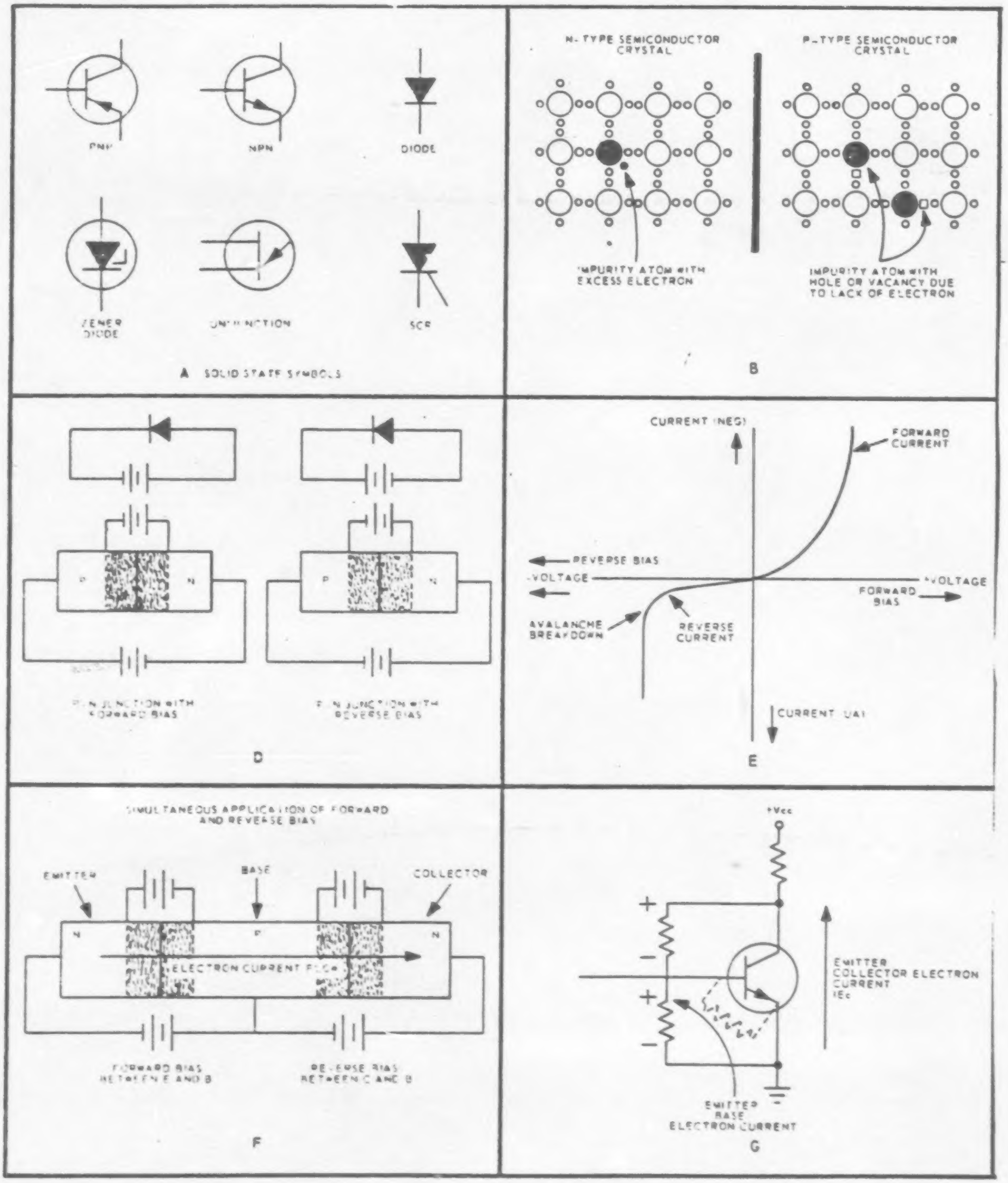
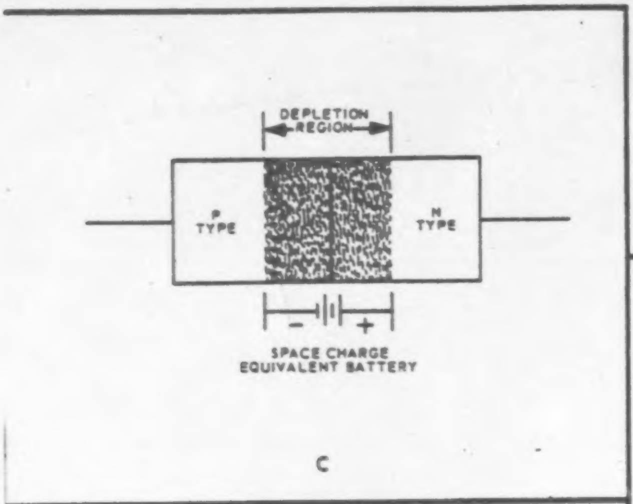
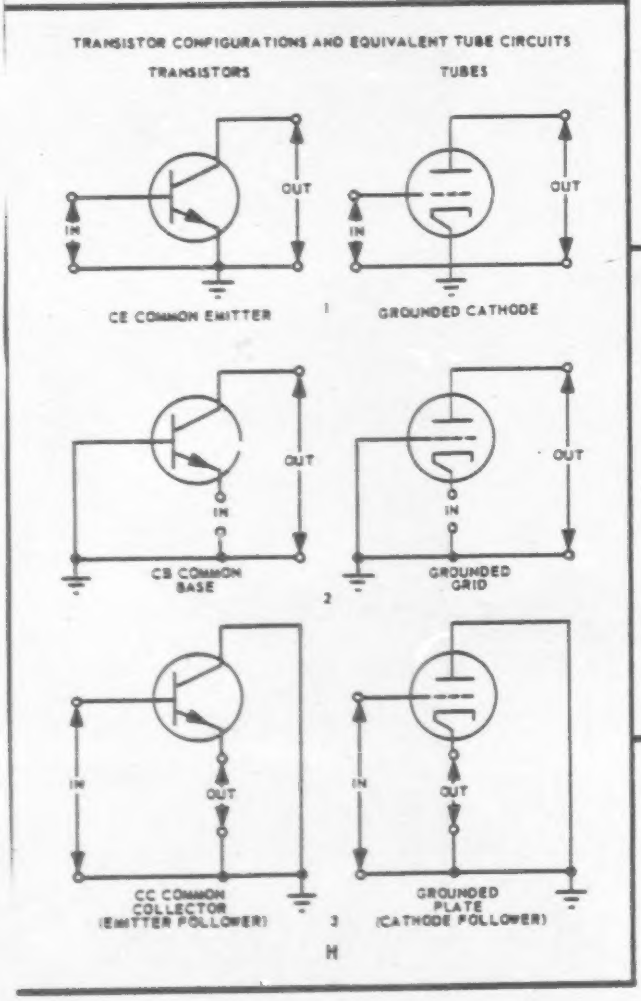

PNP
NPN
DIODE
ZENER DIODE
UNIJUNCTION
SCR
A SOLID STATE SYMBOLS
N-TYPE SEMICONDUCTOR CRYSTAL
P-TYPE SEMICONDUCTOR CRYSTAL
IMPURITY ATOM WITH EXCESS ELECTRON
IMPURITY ATOM WITH HOLE OR VACANCY DUE TO LACK OF ELECTRON
B
P
N
P-N JUNCTION WITH FORWARD BIAS
P-N JUNCTION WITH REVERSE BIAS
D
CURRENT (NEG)
FORWARD CURRENT
REVERSE BIAS
-VOLTAGE
+VOLTAGE
FORWARD BIAS
AVALANCHE BREAKDOWN
REVERSE CURRENT
CURRENT (UA)
E
SIMULTANEOUS APPLICATION OF FORWARD AND REVERSE BIAS
EMITTER
BASE
COLLECTOR
N
P
N
ELECTRON CURRENT FLOW
FORWARD BIAS BETWEEN E AND B
REVERSE BIAS BETWEEN C AND B
F
+Vcc
+
-
+
-
EMITTER COLLECTOR ELECTRON CURRENT IEc
EMITTER BASE ELECTRON CURRENT
G

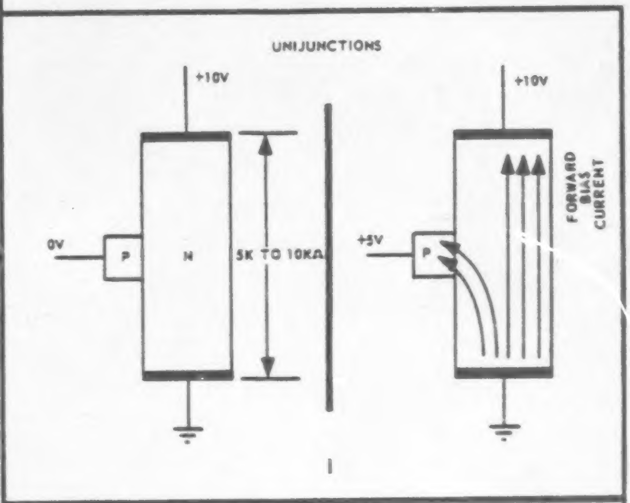
Foldout 1 (continued)


DEPLETION
REGION
P
TYPE
N
TYPE
−
+
SPACE CHARGE
EQUIVALENT BATTERY

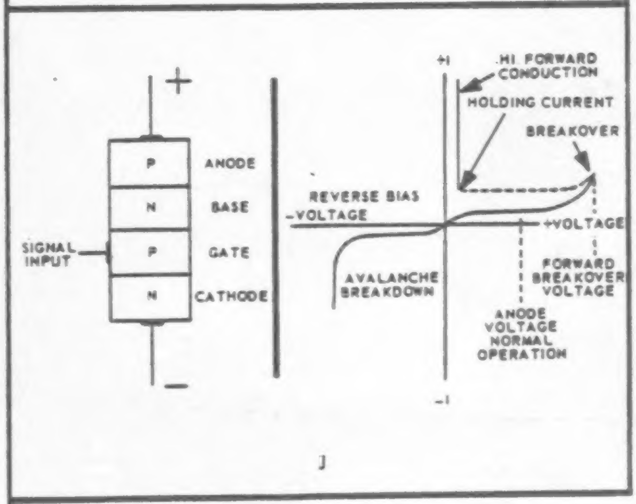
C


TRANSISTOR CONFIGURATIONS AND EQUIVALENT TUBE CIRCUITS
TRANSISTORS
TUBES
IN
OUT
IN
OUT
CE COMMON EMITTER
1
GROUNDED CATHODE
OUT
IN
OUT
IN
CB COMMON
BASE
2
GROUNDED
GRID
IN
OUT
IN
OUT
CC COMMON
COLLECTOR
(EMITTER FOLLOWER)
3
GROUNDED
PLATE
(CATHODE FOLLOWER)

H


UNIJUNCTIONS
+10V
0V
P
N
5K TO 10KΩ
+10V
+5V
P
FORWARD
BIAS
CURRENT

I


+
P
ANODE
N
BASE
P
GATE
N
CATHODE
SIGNAL
INPUT
−
+I
HI FORWARD
CONDUCTION
HOLDING CURRENT
BREAKOVER
REVERSE BIAS
−VOLTAGE
+VOLTAGE
AVALANCHE
BREAKDOWN
FORWARD
BREAKOVER
VOLTAGE
ANODE
VOLTAGE
NORMAL
OPERATION
−I

J

Foldout 1.

Figure A. Solid state symbols.
Figure B. Doped semiconductor crystals.
Figure C. P-n junction.
Figure D. Biased junctions.
Figure E. Voltage-current characteristics.
Figure F. Simultaneous application of forward and reverse bias.
Figure G. Forward bias current flow.
Figure H. Transistor configurations and equivalent tube circuits.
Figure I. Unijunction transistor.
Figure J. Silicon controlled rectifier.

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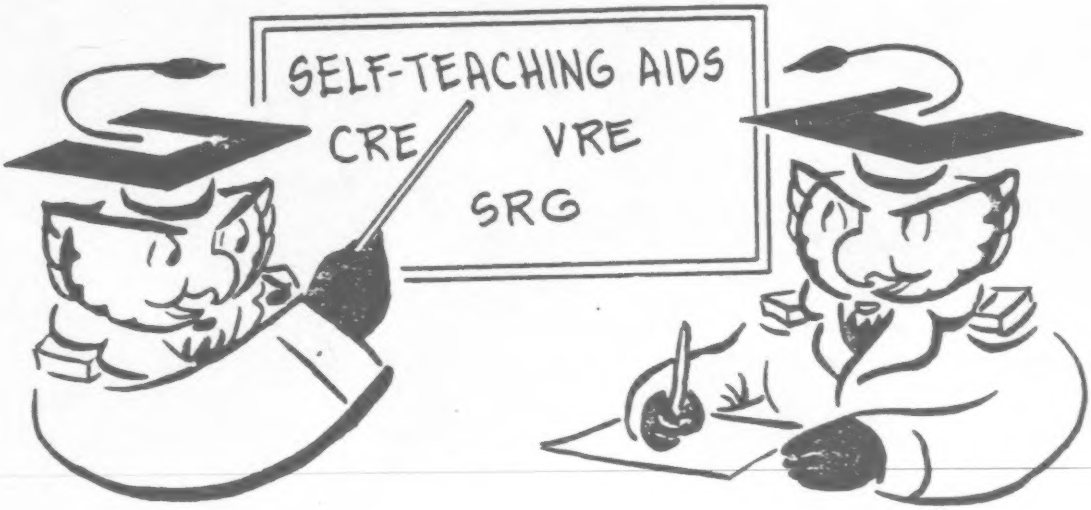
WORKBOOK

Equipment Maintenance



This workbook places the materials you need *where* you need them while you are studying. In it, you will find the Study Reference Guide, the Chapter Review Exercises and their answers, and the Volume Review Exercise. You can easily compare textual references with chapter exercise items without flipping pages back and forth in your text. You will not misplace any one of these essential study materials. You will have a single reference pamphlet in the proper sequence for learning.

These devices in your workbook are autoinstructional aids. They take the place of the teacher who would be directing your progress if you were in a classroom. The workbook puts these self-teachers into one booklet. If you will follow the study plan given in "Your Key to Career Development," which is in your course packet, you will be leading yourself by easily learned steps to mastery of your text.

If you have any questions which you cannot answer by referring to "Your Key to Career Development" or your course material, use ECI Form 17, Student Request for Assistance," identify yourself and your inquiry fully and send it to ECI.

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STUDY REFERENCE GUIDE

1. *Use this Guide as a Study Aid.* It emphasizes all important study areas of this volume.

2. *Use the Guide as you complete the Volume Review Exercise and for Review after Feedback on the Results.* After each item number on your VRE is a three digit number in parenthesis. That number corresponds to the Guide Number in this Study Reference Guide which shows you where the answer to that VRE item can be found in the text. When answering the items in your VRE, refer to the areas in the text indicated by these Guide Numbers. The VRE results will be sent to you on a postcard which will list the *actual VRE items you missed.* Go to your VRE booklet and locate the Guide Number for each item missed. List these Guide Numbers. Then go back to your textbook and carefully review the areas covered by these Guide Numbers. Review the entire VRE again before you take the closed-book Course Examination.

3. *Use the Guide for Follow-up after you complete the Course Examination.* The CE results will be sent to you on a postcard, which will indicate "Satisfactory" or "Unsatisfactory" completion. The card will list *Guide Numbers* relating to the questions missed. Locate these numbers in the Guide and draw a line under the Guide Number, topic, and reference. Review these areas to insure your mastery of the course.

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101	TV in the Air Force: General; Mission of Department of Defense; Mission of Maintenance Unit; Advantages of Television; Instruction, pages 5-9
102	TV in the Air Force: Security; Traffic Control; Surveillance; Weather Service; Hazardous Monitoring; Command Assignments, pages 9-13
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105	Low Voltage Power Supplies: Voltage Regulators, pages 21-27
106	Low Voltage Power Supplies: Constant-Current Regulators; Symptoms and Troubles; High-Voltage Power Supplies: General; Voltage Multipliers, pages 27-31
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123	Color Monitors, pages 111-115

CHAPTER REVIEW EXERCISES

1. In solid state symbols, what do the arrowheads indicate? (4-9)

2. What is the conductivity of a material dependent upon? (4-10)

3. Why are impurities added to semiconductor material? (4-10)

4. Why is the depletion region represented by a battery? (4-11)

5. What is the polarity arrangement of the external battery and barrier potential for forward bias? (4-12)

6. Explain thermal runaway. (4-12)

7. What happens to the barrier potential when reverse bias is applied? (4-13)

8. What is the result of applying an a-c signal to a diode? (4-14)

9. What is the main difference between a normal diode and a Zener diode? (4-15)

10. How is a power gain achieved in a transistor? (4-16)

11. In which direction is a base-collector junction normally baised? (4-17)

12. What is the polarity of the emitter and collector with respect to the base in a forward biased n-p-n transistor? (4-17)

13. What do the letters designate in transistor configuation titles? (4-18)

14. How is the common emitter amplification factor represented? (4-19)

15. What determines whether a unijunction is conducting at a high- or low-level state? (4-21)

16. What is the value of anode voltage required to trigger an SCR called? (4-22)

17. How can the forward breakover point be controlled? (4-23)

MODIFICATIONS

Page 3 of this publication has been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

28. The better the quality desired in a picture.

CHAPTER 2

Objectives: To demonstrate (1) knowledges in power supply requirements for TV systems and (2) skill in troubleshooting these systems.

1. Three major factors that will affect the power supplies needed for a TV system are: (1) the ______ of equipment, (2) the ______ of the equipment, and (3) the ______ within a particular equipment. (4-3)

2. Match the most appropriate power supply requirement in Column B to the components in Column A by writing the alphabetical designator in the blank. (4-4-6)

Column A

1. ___ Camera tube.
2. ___ Picture tube.
3. ___ Receiver tube.
4. ___ Transistor.

Column B

a. Regulated 300v.
b. Regulated 400 ma.
c. Unregulated 17,000v.
d. Unregulated 5v.
e. Regulated 15v.

PAGES 282 & 283 ARE MISSING DUE TO MISNUMBERING.

3. Identify the three basic low-voltage rectifier circuits. (5-2)

4. If the effective secondary voltage is 200 volts a-c at 60 cps, the approximate output of a full-wave bridge rectifier will be _______ d-c volts with a _____-cps ripple frequency. The diodes must withstand a peak-inverse voltage of about _______ volts. (5-3; Fig. 10)

5. What is the ripple frequency of any three-phase full-wave rectifier? (5-4. 10; Fig. 13)

6. If load current decreases for the regulator circuit shown in figure 16.A. what will happen to the current through: (1) the transistor and (2) the series resistor? (5-15)

7. If the input unregulated voltage V_u in figure 17.B. increases, what will happen to the forward bias applied to the transistor and why? (5-23. 24)

8. For the circuit shown in figure 17.C. an adjustment upward on *R*3 causes *Q*2 to conduct (more. less); thus the drop across *Q*1 will (increase. decrease) and V_R will (increase. decrease). (5-25–28; Fig. 17)

9. If the voltage adjust shown in figure 18 is moved downward. what will happen to the positive potentials at the following points? (Answer: *increase, decrease. no change*) (5-30–33)
   a. Base of *Q*2 __________.
   b. Emitter of *Q*4 __________.
   c. Collector of *Q*4 __________.
   d. Base of *Q*3 __________.
   e. Collector of *Q*3 __________.
   f. Base of *Q*7 __________.

10. As a result of an output load current increase in switching regulator circuit (fig. 19). transistor *Q* conducts (more. less). gate pulses are (advanced. delayed), and the conduction time of the SCR's is (increased. decreased). (5-35–37)

11. When the output adjust *R*2 in figure 22 is moved upward, transistor *Q*2 conducts (more, less), thereby causing an (increased, decreased) regulated current to be delivered to the load. (5-41)

12. Using the circuit of figure 9,C, match the symptoms with the most probable trouble. (5-42–46)

Symptoms	*Trouble*
a. Reduced output. no overheating 60-cycle ripple.	___ 1. Open rectifier. ___ 2. Shorted rectifier.
b. Reduced output. 120-cycle ripple.	___ 3. Open capacitor.
c. Reduced output. heat. 60-cycle ripple.	___ 4. Leaking capacitor. ___ 5. Open transformer.
d. No output.	

13. The conventional voltage doubles shown in figure 23 has a sinusoidal voltage across its secondary of 400 volts rms at 500 cps. Determine the following: (6-5, 6)

- *a.* Output voltage _____ d-c volts (approximately).
- *b.* PIV on diodes ______
- *c.* Charge per capacitor _____ d-c volts (approximately).
- *d.* Ripple frequency _____ cps.

14. If a peak voltage input of 150 volts is applied to the cascade multiplier circuit in figure 25.A, the d-c voltage at point c is _____ volts and at point f is _____ volts. (6-12)

15. The cascade multiplier circuit shown in figure 25.B, draws input current only on the _______ alternation. 6-13)

16. State two advantages of a flyback HV system. (6-17, 19)

17. Sketch a flyback HV system having a boost voltage developed from a secondard winding. (6-17)

18. Referring to the HV regulator circuit shown in figure 27.A, and assuming the load voltage tends to increase, indicate whether the voltage becomes more positive, less positive, more negative, less negative, or remains the same at the following points: (6-21–23)

- *a.* Plate of *V3* ______________________.
- *b.* Plate of *V4* ______________________.
- *c.* Suppressor grid of *V1* ______________.
- *d.* Screen grid of *V1* __________________.
- *e.* Control grid of *V1* _________________.
- *f.* Ungrounded side of *C3* _______________.

19. When the voltage adjust in figure 27.B. is moved toward ground, the conduction time of *Q1* _______. How does this affect the HV output? Is the firing frequency of the SCR affected? (6-24–27)

20. It is reported to you that the picture and raster on a monitor suddenly disappear. After making all visual checks and everything (filaments, fuses, and connections), looks normal what check is made next? (6-30, 31)

21. Suppose the HV of figure 27.A. is unstable and higher than normal. What component(s) under what condition(s) would give these symptoms? (6-34, 35)

CHAPTER 3

Objectives: (1) Demonstrate knowledges of the operation, adjustment and repair of sync generators and (2) exercise skill in the use of schematic diagrams.

1. Name three basic sections of a simple noninterlace sync generator. (7-2)

2. State why there is no need for a tie-in between the vertical oscillator and horizontal oscillator in a noninterlace system. (7-3)

3. What sections supply the inputs to the blanking mixer of the simple noninterlace sync generator? (7-2, 3)

4. What outputs does the horizontal oscillator provide in a simple noninterlace system? (7-4)

5. In the simple noninterlace sync system of figure 29, adjustments for a distorted vertical scan can be made in the ______ ______ section. (7-5)

6. What is the purpose of a squarer and peaker section in the multiple-pulse noninterlace sync generator? (7-7)

7. The ___ ___ ______ section, shown in figure 30, narrows the vertical pulse for vertical sync. (7-7)

8. For the multiple-pulse sync system described, the 833-γsec horizontal sync pulse is developed by the ______ section from a horizontal pulse of about _____-γsec duration. (7-8, 9)

9. Indicate whether the sections shown in figure 30 depend upon the vertical oscillator (vo), horizontal oscillator (ho), both, or neither for proper operation. (7-7–10)
   a. Blanking mixer ________.
   b. Vertical drive ________.
   c. Squarer and peaker ________.
   d. Sync mixer ________.
   e. Horizontal blank ________.

10. Sketch the waveforms of blanking mix and sync mix showing their time relationships. (7; Fig. 31)

11. If the vertical blanking pulse is 850 γsec longer than vertical sync, how many 16-7-kc horizontal syncs will appear during vertical blank? (7-9)

12. If the vertical blanking and drive pulses of the multiple-pulse noninterlace sync genera-

tor (fig. 30) are too wide, what section needs adjusting first? (7-10, 11)

13. Referring to figure 31, in what section is there probably trouble if the horizontal pulses of the mixed blanking output are too narrow, but H drive is normal? Why? (7-11)

14. Why must the ratio of horizontal to vertical scan in an interlace system be constant? (8-2)

15. The standard lines per field for interlace in this country are ________. (8-2)

16. Identify four basic sections of an interlace sync generator. (8-3)

17. The 525:1 counter section divides the mo pulses to obtain ______ sync and blank timing. (8-4)

18. List three commonly used counting circuits. (8-6)

19. How can the stability of a blocking oscillator counter be improved? (8-7)

20. Why is the phantastron counter a reliable type? (8-8–12)

21. Referring to figure 35, what is the cathode potential when plate current is cut off? (8-8–10)

22. Draw and label the block diagram of a random interlace sync generator having afc and crystal control. (8-13)

23. What will result if the time difference between the last horizontal pulse and the vertical sync/blank is H instead of alternately H and 0.5H as illustrated in figure 37? (8-14, 16)

24. The absence of ______ ______ during vertical blanking can cause random interlace. (8-16, 24)

25. For calibration of counters using the mo, the afc switch is put in the ____ position. (8-20, 21)

26. In what order should you calibrate the counters in a counter chain? Why? (8-21)

27. Match the signals identified in Column B to the function stated in Column A. (8-24–27)

Column A	Column B
___ 1. Maintains proper horizontal sync during vertical sync time.	*a.* Equalizing pulse.
___ 2. Insures precise timing of the vertical scan.	*b.* Serrating pulse.
___ 3. Maintains proper horizontal sync immediately before and after vertical sync.	*c.* 3H pulse.
___ 4. Provides vertical sync.	*d.* Horizontal sync.

28. The time between the start of vertical sync and the ________ edge of the first serration is set to equal 0.5H. (8-26)

29. What is the function of the notching section? How would you know when it is inoperative? (8-29)

30. Why is the 9H section needed to form the standard sync waveform? (8-31)

31. Refer to the block diagram (fig. 41.A) and determine in which section(s) there is probably trouble if five equalizing pulses records precede vertical sync and seven follow; everything else is normal. (8-33; Fig. 41)

CHAPTER 4

Objectives: (1) To demonstrate knowledges of the function and operation of the vidicon and image orthicon cameras and (2) to show skill in the care, troubleshooting, and repair of the camera chain elements.

1. Give the dimensions for the standard vidicon tube. _____ inch(es) in diameter and _____ inch(es) long. (9-3)

2. Sketch a vidicon tube and indicate the faceplate, signal output terminal, and electron gun. (9-3; Fig. 42)

3. State the purpose of the electron gun. (9-3, 4)

4. A bright image focused on the mosaic of a vidicon for a long period will cause an image ________. (9-5)

5. It (is, is not) necessary to have a lens in place on a vidicon camera to make initial beam adjustment. (9-7)

6. What equipment and conditions are necessary when making final adjustments on a vidicon camera to obtain the best picture definition? (9-8)

7. Sketch a block diagram of a vidicon camera showing the pickup and amplifier stages and show waveform(s) at test points. (9-9; Figs. 43 and 44)

8. Sketch an image orthicon tube and name major elements. (9-11; Fig. 45)

9. State the major construction difference(s) between an image orthicon and a vidicon camera tube. (9-11, 12)

10. Image electrons are accelerated from the IO photocathode to the ______ where they cause secondary emission. (9-11)

11. To set an IO tube on its face may cause damage to the ______ due to loose particles falling in the tube. (9-15)

12. If you were to choose between a vidicon and an image orthicon camera to use in a low-light level studio, which camera would you choose? (9-17)

13. Write in the blanks preceding the following statements the camera pickup tube preferred or is best described by the statement. This will be either a vidicon or image orthicon. (9-17)

a. __________ Operating cost is approximately $0.10 per hour.

b. __________ Average output signal level is approximately 50 millivolts.

c. __________ Output signal level is stable over a wide range of light levels.

d. __________ Inherent tube noise limits the signal-to-noise ratio.

e. __________ Fast-moving objects cause picture smear.

f. __________ Requires simpler external circuitry, therefore smaller cameras.

14. The proper installation of the blower bellows will insure proper ______ as air flow will not be impaired. (9-21)

15. Suppose you are setting up an IO camera and you notice that the target voltage needs adjusting. What is the source of target voltage and where is it adjusted? (9-23, 25)

16. Sketch a block diagram and show the waveforms of the horizontal section of an IO camera. (9-28; Fig. 47)

5. What basic stages comprise each of the following sections? (12-8; Fig. 59)
   a. Video.
   b. Sync.
   c. Vertical.
   d. Horizontal.

6. Match the signal described in Column B to the circuit in which it is found in Column A by placing the alphabetical designator of Column B in the blanks provided in Column A. (12-13–24)

Column A	*Column B*
1. ___ DC restorer.	a. 60-cps sawtooth.
2. ___ Horizontal oscillator.	b. 15.750 pps.
3. ___ Damper.	c. Clamped video composite.
4. ___ Afc.	d. d-c boost.
5. ___ Vertical oscillator.	e. Differentiated sync.
	f. 60-pps blanking.

7. Briefly explain how the sync signals are separated by Q3 in figure 60. (12-14)

8. The vertical sync is separated from the horizontal by means of a/an ________ circuit. (12-16)

9. In figure 60, the picture height is adjusted at the output of the ________ ________ (12-16)

10. What two controls affect the height of the picture? (12-17)

11. Blanking at 60 pps is developed from the ______ ________ stage of figure 60. (12-18)

12. If the horizontal oscillator tended to increase in frequency, how would the afc prevent it? (12-20)

13. Besides frequency, what is a noteworthy difference between the horizontal and vertical oscillator? (12-22)

14. What control sets the frequency of the horizontal oscillator? Where is it located in figure 60? (12-22)

15. What circuits in figure 60 could not function properly if transistor Q10 failed? (12-23, 24)

16. If corner shadowing of the picture is evident, what adjustment should be made? (12-28)

17. Why are numerous video amplifiers used in a master monitor? (13-3)

18. How does the horizontal oscillator frequency control in a master monitor differ from that in a receiver picture monitor? (13-5)

19. Why is a separate high-voltage power supply used in a master monitor? (13-5)

20. The waveform monitor has a horizontal sweep selection of _____ cps for observing the vertical pulse waveforms and _____ cps for observing the horizontal pulse waveforms. (13-9)

21. How is sweep expansion accomplished? (13-10)

22. Using the block diagram in figure 63, match the probable trouble in Column B with the abnormal display described in Column A by writing the alphatical designators of Column B in the blanks in Column A. (13-14–18)

Column A	*Column B*
1. __ Black raster.	a. Horizontal oscillator failure.
2. __ White vertical line.	b. Cathode-to-grid short in kinescope.
3. __ Insufficient height.	c. Gassy CRT.
4. __ Top half white, bottom half black.	d. Weak vertical output amplifier.
	e. High-voltage failure.

CHAPTER 6

Objectives: (1) To apply knowledge of the performance characteristics of the different types of microphones; (2) to identify the functions of an audio control console and audio amplifier; (3) to diagnose troubles from given symptoms by use of schematic diagrams.

1. List the four common types of microphones. (14-1)

2. Match the type of microphone in Column B to the description which describes it best in Column A by writing the alphabetical designators of Column B in the blanks provided in Column A. (14-3, 9, 14, and 16)

Column A	*Column B*
1. __ Uses carbon grains as a variable resistance.	a. Dynamic.
2. __ Makes use of flexing bimorph unit to generate a-c.	b. Carbon.
3. __ It has a coil made of thin metal ribbon attached to the diaphragm.	c. Crystal
4. __ It has two electrodes, one flexing and one rigid.	d. Capacitor

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3. When choosing a microphone on the basis of one having the best frequency range, which of the four major types would be best? (14-18)

4. Suppose you have a studio situation in which a polydirectional microphone is picking up side noise. What adjustment would you make to eliminate this? (14-19)

5. Match the tube configuration listed in Column B to the transistor configuration in Column A by writing the alphabetical designators of Column B in the blanks provided in Column A. (15-2)

Column A	*Column B*
1. ___ CE.	a. Cathode follower.
2. ___ CB.	b. Grounded cathode.
3. ___ CC.	c. Grounded grid.
	d. Phase splitter.

6. Briefly compare tubes and transistors with regard to coupling, gain, and noise. (15-3, 6, and 9; Fig. 76, A)

7. Using figure 74, determine the voltage, current, and power gain for a CE amplifier having a 10K load resistance.* (15-6)

8. The ______ amplifier gives the highest current gains. (15-6)

9. The ______ amplifier gives the highest voltage gains. (15-6)

10. The ______ amplifier gives the highest power gains. (15-6)

11. With regard to input impedance in the audio range, identify the amplifier listed in Column B and match it to the characteristic described in Column A by writing the alphabetical designators of Column B in the blanks provided in Column A. (15-7)

Column A	*Column B*
1. ___ Highest impedance.	a. CC.
2. ___ Lowest impedence.	b. CE.
3. ___ Most frequency dependent.	c. CB.

12. The noise factor of a transistor varies (inversely, directly) with frequency in the audio range. (15-11)

13. What are the distinctive features of each of the following: preamplifier, driver, and power amplifier? (15-8, 20–23)

14. Why can higher efficiency and better fidelity be attained with push-pull operation? (15-23)

15. For what class of operation should the bias on a push-pull amplifier be adjusted for each of the following: (15-23–29)
    a. Maximum efficiency ______.
    b. Maximum fidelity ______.
    c. High efficiency and fidelity ______.

16. In figure 83, if class A operation is to be adjusted to class AB, would you increase or decrease R? Why? (15-28)

17. List the major functional units which are a part of the audio console. (16-2)

18. Mixing action is accomplished by adjusting the ______ of the various inputs to accomplish a composite output of the desired balance. (16-6)

19. Sketch a signal circuit for microphone number 1 to program line out (16-9, Fig. 88)

20. The program director calls you to say there is some background hum in his headset. What would you check first? (16-12)

21. The output for program audio is set for a given level on the ______. (16-14)

22. Use the block diagram in figure 88 and determine the most probable source of trouble. Microphone number 3 is in operation on stage and microphone numbers 1 and 2 on the floor; the control room operator says that he is picking up static when he asks for a signal boost from the stage microphone. The floor microphones are giving plenty of signal and no static. (16-18, 19)

CHAPTER 7

Objectives: (1) To test understanding of the principles and requirements of color TV; (2) To identify features of a color camera; (3) to demonstrate skill in the adjustment and alignment of a color camera; and (4) to demonstrate knowledge in the maintenance and troubleshooting of a color monitor.

1. For observing enemy terrain, a good choice would be ______ TV because it can better reveal any ______ areas. (17-6)

2. The sensation of colors, other than the primaries, is achieved in color TV by mixing various proportions of ______ and ______. (17-10)

3. Identify the properties of color that must be transmitted to achieve color fidelity. (17-14) ______

4. The NTSC color broadcasting system requires which of the following? (Check those required.) (17-15–19)
   a. _____ Compatibility of color and monochrome.
   b. _____ Color to use a wider bandwidth.
   c. _____ Color and monochrome both use AM.
   d. _____ Chrominance information to be interleaved with monochrome.
   e. _____ Color and monochrome to use the same sync waveforms but different frequencies.
   f. _____ The color carrier to be suppressed prior to transmission.

5. When televising a detailed weather map, what can be done to improve color perception? (17-17)

6. What units are found in a color camera chain that are *not* used in a monochrome camera chain? (17-21)

7. List five requirements of an NTSC color system that are additional to those of a standard monochrome system. (17-21)

8. Draw a block diagram of the NTSC camera chain. (18-1; Fig. 94)

9. List some of the major differences between the monochrome and color cameras. (18-2)

10. Why is it necessary to divide the light spectrum in the optical system of a color camera? (18-3)

11. What would possibly happen if the optical orbiter were not operating? (18-4)

12. Which filter(s) are used to balance the light on the camera pickup tubes. (18-7)

13. List some of the improvements made in image orthicons used for color operations. (18-10)

14. Indicate what controls on the camera, the viewfinder, and the camera control panel make a color system easily distinguishable from monochrome systems. (18-13–19)

15. What camera adjustments are made to correct the shape of the red image to make it the same shape as the green image? (18-15)

16. The image orthicon tube provides signal amplification in addition to its prime function. How can the color camera IO be adjusted? (18-15)

17. State the basic difference(s) in the preamplifiers used in monochrome and color IO cameras? (18-16)

18. Name the functions performed by the processing amplifier in a color camera chain. (18-20)

19. From what equipment listed in Column B does the processing amplifier obtain the inputs specified in Column A. Specify by writing the alphabetical designators of Column B in the blanks provided in Column A. (18-21, 22)

Column A	*Column B*
1. __ H-drive.	a. Color camera.
2. __ Composite video.	b. Control panel.
	c. Sync generator.
3. __ B, G, and R signals.	d. Colorplexer.

20. How do the line and field frequencies established in the sync generator section of an NTSC color system compare with those of a standard monochrome system? (18-24)

21. The burst flag pulses are timed to place the ______ sync on the back porch of the horizontal ______ pulse. (18-25)

22. Match the frequency listed in Column B to the signal identified in Column A by writing the alphabetical designators of Column B in the blanks provided in Column A. (18-23–25)

Column A	*Column B*
1. ____ Color carrier.	a. 59.94 cps.
2. ____ Burst flag.	b. 31.47 kc.
3. ____ H-drive.	c. 3.58 mc.
	d. 60 cps.

23. Draw a block diagram of a NTSC colorplexer. (18-26; Fig. 96)

24. The color signals that are used for modulation are designated ________ and ____; each is obtained from a ________ (18-27)

25. Match the hue listed in Column B to the signal identified in Column A by writing the alphabetical designators of Column B in the blanks provided in Column A. (18-27, 28)

Column A	*Column B*
1. ____ +I.	a. White.
2. ____ −Q.	b. Red.
3. ____ +Q.	c. Cyan.
4. ____ +Y.	d. Magenta.
5. ____ −I.	e. Orange.
	f. Yellowish-green.

26. Why are the Y and I signals additionally delayed? (18-29)

27. The I modulated signal is ______ degrees out of phase with the reference carrier and the Q modulated signal is ______ degrees out of phase with the I modulated signal. (18-30, 31)

28. What information is contained in the output signal from the mixer of a colorplexer? (18-32)

29. The chrominance signal changes phase as ______ changes and varies in amplitude as ______ varies. (18-36)

30. What sections are essentially different for a single-input color monitor as compared to a three-input type? (19-1, 2; Fig. 103)

31. The luminance section of a NTSC color monitor corresponds to the ______ section of a standard monochrome monitor. (19-3)

32. Draw a block diagram of the burst control oscillator section of a NTSC color monitor. (19-5)

33. The d-c voltage applied to control the color killer is developed by the ______ ______. (19-8)

34. The color killer cuts off the ______ ______ when a ______ signal is received. (19-9)

35. The I and Q signals are detected by ______ demodulators. (19-10)

36. Why are phase splitters needed in the chrominance demodulator section? (19-11)

37. Color temperature is adjusted by means of a potentiometer in the ______ and ______ matrix. (19-13)

38. Match the items in Column A to a function(s) in Column B by writing the numerical designators of Column A in the blanks provided in Column B. (19-15–21)

Column A

1. Phosphor dot.
2. Trios.
3. Shadow mask.
4. Hole in mask.
5. Three-gun assembly.

Column B

a. __ One of three that glows a specific color.
b. __ Triangular group that will glow with three colors.
c. __ Shields the screen from stray electrons.
d. __ Permits passage of

Column A

6. External shield.

Column B

the converged beams.

e. __ Provides three electron beams.

f. __ Provides protection from stray magnetic fields.

39. How can you determine if convergence, purity, or temperature adjustments are necessary? (19-22-27)

ANSWERS FOR CHAPTER REVIEW EXERCISES

Chapter 2

ANSWERS FOR CHAPTER REVIEW EXERCISES

1. The direction of conventional current flow. (4-9)
2. The number of free electrons available in the material. (4-10)
3. To increase the conductivity to a wanted value. (4-10)
4. The region is an electric field or difference of potential. (4-11)
5. The polarities are arranged so that the potentials are in series and aiding. (4-12)
6. Heat generated by current flow causes a decrease in resistance and a further increase in current. This will continue until the device is destroyed. (4-12)
7. The barrier potential will increase to equal the reverse bias potential. (4-13)
8. Rectification. (4-14)
9. Breakdown in the reverse direction does not destroy the Zener device. (4-15)
10. Signal input to the forward biased or low resistance section is transferred to a reverse biased or high resistance element. (4-16)
11. Normally reverse biased. (4-17)
12. The emitter is negative with respect to the base. The collector is positive with respect to the base. (4-17)
13. The C stands for common, the second letter indicates the emitter, base, or collector. (4-18)
14. Beta, β, or h_{fe}. (4-19)
15. Whether the p-n junction is forward or reverse biased. (4-21)
16. Forward breakover voltage. (4-22)
17. A gate current increase will lower the anode voltage value required for breakover. (4-23)

CHAPTER 2

1. Types, complexity, components. (4-3)
2. 1. b.
   2. c.
   3. a.
   4. c.

   (4-4–6)
3. Half-wave, full-wave center-tap, and full-wave bridge. (5-2)
4. 280v, 120 cps, 280v. (5-3; Fig. 10)
5. Six times the input line frequency; thus, 60 cps would produce a 360-cps ripple. (5-4, 10; Fig. 13)
6. (1) The transistor current increases.
   (2) The current through the series resistor remains constant. (5-15)
7. Forward bias decreases because the emitter voltage becomes more positive; therefore, it approaches the base positive voltage which is held constant by the Zener diode. (5-23, 24)

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8. More, decrease, increase. (5-25–28; Fig. 17)
9. a. Increase.
   b. Decrease.
   c. No change.
   d. Decrease.
   e. Decrease.
   f. Decrease.
   (5-30–33)
10. Less, advanced, increased. (5-35–37)
11. Less, decreased. (5-41)
12. *a.* 1.
    b. 4.
    c. 2.
    d. 5.
    (5-42–46)
13. *a.* 1120. *b.* 1120. *c.* 560. *d.* 1000. (6-5, 6)
14. 450, 900. (6-12)
15. Positive. (6-13)
16. Easy filtering and dependency on horizontal output. (6-17, 19)
17. Check your sketch with figure 26,A. (6-17)
18. *a.* Less negative.
    b. Less positive.
    c. Remains the same.
    d. Less positive.
    e. Less negative.
    f. Remains the same (practically).
    (6-17)
19. Increases. The HV becomes more positive. No, because gating frequency is unaffected. (6-24–27)
20. Check the resistor in the high-voltage lead. (6-30, 31)
21. If *V*4 has an open plate, cathode, or filament, the screen grid voltage of *V*1 will increase, giving high amplitude output. This higher output will not be sensed and corrected because *V*4 is open. (6-34, 35)

CHAPTER 3

1. Vertical oscillator, horizontal oscillator, and blanking mixer. (7-2)
2. Frequency shifts between the vertical oscillator and horizontal oscillator will not ordinarily affect the operation of a noninterlace system to a noticeable degree. (7-3)
3. Vertical oscillator and horizontal oscillator. (7-2, 3)
4. Horizontal sync, blank, and scan; also high-voltage excitation. (7-4)
5. Vertical oscillator. (7-5)
6. To provide sharp pulses to precisely synchronize the vertical oscillator to the 60-cps line frequency. (7-7)
7. Vertical drive shaper. (7-7)
8. Horizontal drive shaper, 1666. (7-8, 9)
9. *a.* Both.
   b. Vo.
   c. Neither.
   d. Both.
   e. Ho.
   (7-7–10)
10. Check your sketch with figure 31. (7: Fig. 31)
11. 14. (7-9)
12. The vertical amplifier and clipper section should be adjusted first to narrow the vertical blanking pulse. This adjustment will also narrow the vertical drive pulse, but further adjustment of the vertical drive shaper may be necessary to obtain the proper vertical drive pulse duration. (7-10, 11)
13. It is likely that the horizontal blanking shaper is not functioning properly because normal H drive would indicate that the horizontal oscillator is operating normally. This can be checked at TP5. (7-11)
14. Unless the ratio of horizontal to vertical scan is held constant, the lines per field will change and the system cannot be designed to interlace. (8-2)
15. 262 + ½. (8-2)
16. a. 31.5 kc mo.
    b. 2:1 counter.
    c. 525:1 counter.
    d. H-V mixer.
    (8-3)
17. Vertical. (8-4)
18. Multivibrator, blocking-oscillator, and step counter. (8-6)
19. Insertion of a resonant circuit as illustrated in figure 34 can improve stability of a blocking-oscillator counter. (8-7)
20. The phantastron counter is reliable since it is a stable circuit that cannot be easily pretriggered (note e_p waveform and function of D_1 in fig. 35). (8-8–12)
21. When plate current is cut off, e_p rises to B+; the e_k waveform in figure 35 shows e_k = 40v at this time. (8-8–10)
22. Check your block diagram with figure 36. (8-13)
23. If the time difference between the last horizontal pulse and the vertical sync blank is repeatedly H, no interlace will occur. Fields will fall upon each other and the lines per frame will be half that of an interlaced frame. (8-14, 16)
24. Horizontal sync or equalizing pulses. (8-16, 24)
25. OFF. (8-20, 21)

26. Counters must be calibrated successively from the mo end to the output because each counter depends upon the proper output from the one that precedes it. (8-21)
27. 1. b.
    2. a.
    3. a.
    4. c.
    (8-24–27)
28. Trailing. (8-26)
29. The notching pulses eliminate the equalizing pulses when only horizontal sync pulses should be present. If the notching section were inoperative, equalizing pulses would appear midway between horizontal sync pulses. (8-29)
30. The 9H section is needed to block the horizontal and notching pulses (fig. 41.B, signals b and c) during the time that equalizing pulses and serrated vertical sync are formed. (8-31)
31. The vertical pulse delay section because the 3H pulse is being triggered too soon. (8-33; Fig. 41)

CHAPTER 4

1. 1 inch, 6 inches. (9-3)
2. See figure 42. (9-3; Fig. 42)
3. To produce and give initial control to the electron beam. (9-3, 4)
4. Burn. (9-5)
5. Is not. (9-7)
6. A resolution chart; proper illumination; vertical, horizontal, and beam controls adjusted; lens in position and preset; electrical focus ready for adjustment. (9-8)
7. See figures 43 and 44. (9-9; Figs. 43 and 44)
8. See figure 45. (9-11; Fig. 45)
9. The image orthicon has an image accelerator section and a beam multiplier, whereas the vidicon does not. (9-11, 12)
10. Target. (9-11)
11. Target. (9-15)
12. Image orthicon. (9-17)
13. *a.* Vidicon.
    b. Image orthicon.
    c. Image orthicon.
    d. Image orthicon.
    e. Vidicon.
    f. Vidicon.
    (9-17)
14. Cooling. (9-21)
15. The voltage is supplied from a voltage divider network located on the camera control chassis and is adjusted by a potentiometer. The voltage source is a negative HV rectifier in the camera and B+ supply on the camera control chassis. (9-23, 25)
16. Compare to figure 47. (9-28; Fig. 47)
17. a. Remote adjustments of voltages in camera.
    b. Correction for shading.
    c. Correction for black and white compression.
    d. Provision for signal amplification.
    e. Adjustment for proper blanking and black level.
    f. Addition of sync pulses.
    (10-2)
18. Working with the camera man, adjust the remote controls until the voltages applied to the camera give the best focus and picture resolution (viewed on the picture monitor). If necessary, adjust to correct for shading, black or white compression, blanking, and black level. (10-3)
19. a. At the output of the first video amplifier.
    b. In the gray scale amplifier.
    c. At the input of the first video amplifier.
    d. At the output of the last video amplifier.
    e. In the clipper amplifier.
    (10-4–7; Fig. 48)
20. Black stretch is achieved in the circuit illustrated in figure 49 by adjusting the cathode bias when S1 and S3 are in the Stretch position and S2 is set at Normal. This is accomplished with potentiometer R2 which causes the operating point of the tube to shift so that the signal's black positions are amplified more than normal. (10-7)
21. Troubles could be a fault in the horizontal pulse amplifier and/or the horizontal shading control. (10-8)
22. Since the field camera control unit is designed for portability, it is made compact, with the result that some of its controls are less conveniently located than those of a studio console type. (10-9)
23. Check your drawing with figure 50. (11-6; Fig. 50)
24. Use program transfer switch to connect preview channel to program output and the fader channel to preview output. (11-6)
25. 1. c.
    2. e.
    3. d.
    (11-9)
26. 1. c.
    2. b.
    3. a.
    (11-11)
27. Isolation amplifiers are used at junction points in a distribution system. (11-11)
28. Waveform or shape. (11-11)

29. Broadens or increases. (11-17)
30. Check your sketch against figure 55. (11-22; Fig. 55)
31. A CC amplifier, which is the counterpart of a cathode follower, has maximum degenerative feedback and therefore excellent frequency response. (11-23)
32. In figure 56.A. transistor Q1 is connected as a CC amplifier and Q2 as a CE amplifier. In figure 56, B, Q1 is connected as a CC amplifier, Q2 as a CE in cascode with Q3 which is connected as a CB amplifier. (11-28; Fig. 56)
33. Frequency compensation is not needed when direct coupling, degenerative feedback, and/or low-gain circuitry is employed to give the desired broadband response. (11-28)

CHAPTER 5

1. 1, c; 2, b; 3, c; 4, a. (12-1, 2)
2. Master. (12-2)
3. Check your diagram against figure 57. (12-3)
4. The viewfinder monitor does not contain a sync separator because its input from the camera has no sync information. (12-3)
5. *a.* Video amplifiers and d-c restorer. (12-8; Fig. 59)
   b. Sync separator and pulse amplifiers.
   c. Vertical oscillator and amplifier.
   d. Afc, horizontal oscillator, pulse amplifier, and damper.
6. 1. c.
   2. b.
   3. d.
   4. e.
   5. a.
   (12-13–24)
7. The sync pulses are the most negative-going portion of the input signal to the base Q3 which is self-biased well below cutoff; therefore, only these pulses drive the p-n-p transistor to conduction and appear as positive-going pulses on Q3's collector. (12-14)
8. Integrating (long-time constant RC). (12-16)
9. Vertical oscillator. (12-16)
10. Both the height and vertical linearity controls affect the height of the picture. (12-17)
11. Vertical output. (12-18)
12. If the horizontal oscillator frequency increases slightly, the sawtooth fed to the phase detector (at TP3) will produce an error voltage (see fig. 61, C) that increases the negative bias on Q7's base; thus, the bias on Q8's base decreases (becomes less negative) thereby reducing the blocking rate to counteract the frequency increase. (12-20)
13. The horizontal oscillator generates a pulse output whereas the vertical oscillator develops a sawtooth output. (12-22)
14. The horizontal hold control establishes the bias and therefore the frequency of the horizontal oscillator. In figure 60, this control is seen to be in the afc d-c amplifier stage. (12-22)
15. If Q10 failed the following circuits would not function properly: horizontal deflection, horizontal blanking, high-voltage rectifiers, damper, video output amplifier (no boost voltage), and afc (no feedback). (12-23, 24)
16. The picture correction magnet should be adjusted to eliminate corner shadowing. (12-28)
17. Numerous video amplifiers are needed in a master oscillator to obtain the broadband response for high fidelity. (13-3)
18. A master monitor's horizontal oscillator frequency is controlled directly by the horizontal sync, whereas a receiver picture monitor uses a d-c output from an afc arrangement. (13-5)
19. The stringent requirements for high voltage are best met with a separate well-regulated supply. (13-5)
20. 30, 7875. (13-9)
21. An expanded sweep signal is developed by clipping and amplifying the normal sweep as illustrated in figure 64. (13-10)
22. 1. e.
    2. a.
    3. d.
    4. b.
    (13-14–18)

CHAPTER 6

1. a. Dynamic.
   b. Carbon.
   c. Crystal.
   d. Capacitor. (14-1)
2. 1. b.
   2. c.
   3. a.
   4. d.
   (14-3, 9, 14, and 16)
3. Dynamic. (14-18)
4. Set the shutter aperture to open, making it bidirectional. (14-19)

5. 1. b.
   2. c.
   3. a.
   (15-2)
6. The types of coupling used for tubes and transistors are basically the same; however, the impedance values involved are much lower for transistors. Depending on the load, gains equal to those of tube audio amplifiers can be obtained with transistor audio amplifiers. Transistors are ordinarily noisier than tubes, but can be operated to obtain low noise factors. (15-3, 6, and 9; Fig. 76,A).
7. Voltage gain = 250, current gain = 12, and power gain = 40 db are the indicated values in figure 74 for a CE amplifier. (15-6)
8. CC. (15-6)
9. CB. (15-6)
10. CE. (15-6)
11. 1. a.
    2. c.
    3. a.
    (15-7)
12. Inversely. (15-11)
13. Preamplifiers are characterized by their low power levels and comparatively low noise factors. Drivers are medium power linear amplifiers. Power amplifiers operate at relatively high power levels; therefore, push-pull arrangements are used to obtain higher efficiencies. (15-8, 20–23)
14. Higher efficiencies can be attained because push-pull amplifiers will give linear operation when operated class AB or B. Higher fidelity is attainable because even-harmonic distortion is minimized for class A operation and reduced for class AB operation. (15-23)
15. a. Class B. (15-23–29)
    b. Class A.
    c. Class AB.
16. Increase R. This makes the bases less positive; thus, it biases the n-p-n transistors into cutoff for a portion of each cycle. (15-28)
17. a. Amplifiers. c. Mixers.
    b. Switches. d. Monitors.
    (16-2)
18. Gain. (16-6)
19. See figure 88. (16-9)
20. Hum balance. (16-12)
21. VU meter. (16-14)
22. The mixer or gain control connected to the amplifier for microphone number 3 probably has a dirty wiper arm. This could cause a weak signal which would mean more gain required. It could cause erratic action and thus a static to be heard by the control room operator or program monitor. (16-18, 19)

CHAPTER 7

1. Color, camouflaged. (17-6)
2. Blue, green, and red. (17-10)
3. Hue, saturation, and brightness. (17-14)
4. a. ✓ ; b.__; c. ✓ ; d. ✓ ; e. ✓ ; f. ✓ .
   (17-15–19)
5. Move in or use a zoom lens for closeups so the image is larger on the pickup tube face. The larger the image, the better the color perception. (17-17)
6. Processing amplifier and colorplexer. (17-21)
7. a. Closer tolerances
   b. More complex units
   c. Special optical system
   d. Three camera tubes
   e. A 3.58-mc sync signal.
   (17-21)
8. Check your drawing with figure 94. (18-1)
9. a. Color camera is larger and has more circuitry.
   b. Color camera has three or more pickup tubes, whereas monochrome uses only one.
   c. Color camera has a more complex optical system.
   (18-2)
10. The color television camera must have a blue, green, and red light image. (18-3)
11. There would be danger of image burn to all three pickup tubes. (18-4)
12. The neutral density filters reduce the light on the red and green tubes so that it matches the light on the blue tube. (18-7)
13. a. Reduced screen-to-target spacing
    b. Improved photocathode
    c. A micromesh screen
    d. Better dynode construction
    (18-10)
14. a. The pushbuttons on the viewfinder.
    b. The skew and Q controls in addition to the controls for three channels rather than one on the camera.
    c. The colored knobs for three separate channels, the master iris, and the master pedestal control on the camera control panel.
    (18-13–19)
15. Adjust red skew control for rectangular shape, Q control for linearity. (18-15)
16. In the color camera a dynode gain control is provided for adjusting each IO tube. (18-15)

303

17. The preamplifiers used in color cameras are adjustable. (18-16)
18. a. Video amplification
    b. Cable compensation
    c. Shading and gamma correction
    d. Regeneration of drive pulses and blanking pulse
    e. Generation of test signals
    f. Electronic switching
    (18-20)
19. 1-c; 2-d; 3-b. (18-21, 22)
20. They are slightly lower. (18-24)
21. 3.58 mc, blanking, (18-25)
22. 1-c; 2-b; 3-b. (18-23–25)
23. Check your diagram with figure 96. (18-26; Fig. 96)
24. I and Q; matrix. (18-27)
25. 1-e; 2-f; 3-d; 4-a; 5-c. (18-27, 28)
26. Because the Q signal is delayed most by its filter. (18-29)
27. 57, 90. (18-30, 31)
28. The output signal from the mixer unit of a colorplexer contains luminance, chrominance, and sync information. (18-32)
29. Hue, luminance or brightness. (18-36)
30. The chrominance demodulator, burst control oscillator, and matrix sections. (19-12; Fig. 103)
31. Video. (19-3)
32. Check your drawing with figure 104. (19-5)
33. Phase detector. (19-8)
34. Bandpass amplifier, monochrome. (19-9)
35. Synchronous. (19-10)
36. Because negative and positive I and Q signals are needed as inputs to the matrix section to form the B, G, and R signals. (19-11)
37. B, G. (19-13)
38. a-1; b-2; c-3; d-4; e-5; f-6. (19-15–21)
39. For convergence, look for color definition at edges. For purity, look for hues of color instead of pure color. For temperature, rotate brightness control and look for background change. (19-22–27)

311

STOP— 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER. 2. USE NUMBER 1 PENCIL.

30455 01 21

REVIEW EXERCISE

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use only medium sharp #1 black lead pencil for marking answer sheet.
4. Use a clean eraser for any answer sheet changes, keeping erasures to a minimum.
5. Take action to return entire answer sheet to ECI.
6. Keep Volumn Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks.
   Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than with a #1 black lead pencil.

NOTE: The 3-digit number in parenthesis immediately following each item number in this Volume Review Exercise represents a Guide Number in the Study Reference Guide which in turn indicates the area of the text where the answer to that item can be found. For proper use of these Guide Numbers in assisting you with your Volume Review Exercise, read carefully the instructions in the heading of the Study Reference Guide.

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305

Multiple Choice

Note: The first three items in this exercise are based on instructions that were included with your course materials. The correctness or incorrectness of your answers to these items will be reflected in your total score. There are no Study Reference Guide subject-area numbers for these first three items.

1. The form number of this VRE (or CE) must match

   a. the form number on the answer sheet.
   b. the number of the Shipping List.
   c. my course number.
   d. my course volume number.

2. So that the electronic scanner can properly score my answer sheet, I must mark my answers with a

   a. number 1 black lead pencil.
   b. pen with blue ink.
   c. ball point or liquid-lead pen.
   d. pen with black ink.

3. If I tape, staple or mutilate my answer sheet; or if I do not cleanly erase when I make changes on the sheet; or if I write over the numbers and symbols along the top margin of the sheet,

   a. my answer sheet will be unscored or scored incorrectly.
   b. my answer sheet will be hand-graded.
   c. I will be required to retake the VRE (or CE).
   d. I will receive a new answer sheet.

CHAPTER 1

4. (102) Which of the following is an example of using television to monitor a hazardous situation?

   a. Observing personnel entering security areas.
   b. Observing the fuel-handling operation in a nuclear reactor power plant.
   c. Observing vehicular movement in heavy traffic areas.
   d. Observing the techniques of a highly skilled surgeon.

5. (103) Which of the following activities requires an elaborate video system?

   a. Monitoring a door or gate.
   b. Surveillance of traffic.
   c. Production of news releases.
   d. Weather briefing.

6. (103) In which application would closed-circuit television most likely be used?

   a. Intercontinental communication.
   b. Photographing the moon.
   c. Home educational programs.
   d. Flight crew briefing.

7. (101) Which of the following is an advantageous use of television in the Defense Communications Systems?

   a. Providing entertainment for all personnel.
   b. Providing immediate transmission of information.
   c. Eliminating the need for personal briefings of flight crews.
   d. Eliminating the need for airfield traffic control towers.

8. (103) What is the classification of a video system using two or more cameras, a switcher, and more than one monitor?

   a. Fundamental.
   b. Closed-circuit.
   c. Elaborate.
   d. Moderate.

9. (100) If a 3-level airman is assigned to an open 7-level position, which of the following actions is appropriate?

   a. Award the airman the 7-level AFSC if he passes a 7-level test.
   b. Award the airman a temporary grade of E-5.
   c. Place the airman on OJT to the 5-level AFSC.
   d. Award the airman the 7-level AFSC after 1 year's service in the position.

10. (101) Activities of the Defense Communications Agency are directed by the

    a. Joint Chiefs of Staff.
    b. Defense Intelligence Agency.
    c. Communications Satellite Project.
    d. Defense Atomic Support Agency.

11. (100) Which of the following is an area of responsibility of the technician, but *not* of the repairman?

    a. Use of associated test equipment.
    b. Installation of television systems and equipment.

c. Correction of equipment malfunctions.
d. Major modification of television systems and equipment.

12. (101) Which of the following is an application of instructional television?

a. Direction of aircraft ground movement.
b. Monitoring of sensitive areas.
c. Briefing of flight crews.
d. Reconnaissance of terrain.

CHAPTER 2

13. (106) Why is regulation poor in a cascade voltage doubler?

a. It is a full-wave rectifier.
b. Its output capacitor is charged only once per cycle.
c. It develops twice the peak input voltage.
d. Both input and output can have one side grounded.

14. (105) In figure 16,B, of the text, if the load current increases, the regulator transistor

a. passes more current.
b. base-to-emitter bias decreases.
c. emitter voltage increases.
d. base voltage increases.

15. (107) The boost voltage developed in a flyback HV system is

a. produced when the HV rectifier conducts.
b. produced by voltage doubling.
c. caused by exciting the vertical output stage.
d. produced by using a damper diode.

16. (104) What electronic components in a TV system generally require well-regulated d-c voltages?

a. VR tubes and camera tubes.
b. VR tubes and Zener diodes.
c. Receiver tubes and transistors.
d. Picture tubes and rectifiers.

17. (106) For a single-phase bridge rectifier circuit with an LC filter, what is probably the trouble if the d-c output is low and a ripple having the input frequency is present?

a. An open filter capacitor.
b. An open-circuited rectifier.
c. A leaky filter capacitor.
d. A short-circuited rectifier.

18. (104) A single-phase bridge rectifier has an effective input voltage of 220 volts a-c at a frequency of 60 cps. The approximate output of the rectifier will be

a. 154 vdc with a 60-cps ripple voltage.
b. 154 vdc with a 120-cps ripple voltage.
c. 308 vdc with a 120-cps ripple voltage.
d. 308 vdc with a 240-cps ripple voltage.

19. (104) As compared to three-phase rectifiers, single-phase rectifiers

a. have a ripple of lower amplitude.
b. have higher ripple frequencies.
c. are smaller and less costly.
d. have lower peak inverse voltage ratings.

20. (105) What occurs in the regulator shown in figures 17,C, of the text, if the output voltage tends to increase?

a. The forward bias on Q2 increases.
b. The transistor Q1 conducts more current.
c. The Zener diode conducts less current.
d. The collector voltage of Q2 goes more positive.

21. (107) For the regulated HV system shown in figure 27,B, of the text, what happens if the VOLTAGE ADJUST is moved upward (away from ground)?

a. Transistor Q1 conducts longer.
b. Shock excitation decreases in amplitude.
c. Capacitor C1 charges to a lower voltage.
d. The SCR fires more frequently.

CHAPTER 3

22. (109) What is the purpose of a resonant stabilizer circuit in an interlace system?

a. To insure proper count.
b. To stabilize the horizontal oscillator.
c. To stabilize the vertical oscillator.
d. To insure proper operation of the AFC.

23. (110) The equalizing pulses have a repetition rate of 31.5 kc to properly synchronize the

a. horizontal scan frequency.
b. vertical and horizontal oscillators and produce line pairing.
c. vertical oscillator during vertical blanking.
d. alternate fields and produce interlaced scanning.

24. (108) What stage in figure 29 of the text maintains a stable output from the 60-cps oscillator?

a. Mixer blanking buffer.
b. Vertical sync buffer.
c. Horizontal sync buffer.
d. Blanking mixer.

25. (110) Serrations are present in the vertical sync pulse of a standard interlace sync generator to insure

a. proper retrace of the beam during vertical blanking.
b. synchronization of the vertical oscillator during vertical blanking.
c. synchronization of the horizontal oscillator during vertical blanking.
d. proper interlace of the scan lines.

26. (108) In figure 31 of the text, if the vertical blanking pulses applied to the blanking mixer were too narrow, but the vertical drive was normal, where would the probable trouble be?

a. Squarer and peaker.
b. Vertical oscillator.
c. Vertical amplifier and clipper.
d. Vertical blank shaper.

27. (108) The output of the vertical oscillator of the simple noninterlace system in figure 29 of the text is formed

a. in the blanking mixer and locked by the 60-cps line frequency.
b. by the 60-cps line frequency and locked by the horizontal frequency.
c. across the vertical oscillator blocking capacitor and locked to the 60-cps line frequency.
d. across the horizontal blocking capacitor and locked to the vertical frequency.

28. (109) The fixed relationship between the master oscillator and the counters in figure 32 of the text maintains a

a. sequential line scan rate.
b. constant number of lines per frame.
c. constant number of fields per second.
d. varying number of lines per second.

29. (109) What are the three basic types of counter circuits?

a. Step-counter, blocking oscillator, and multivibrator.
b. Step-counter, resonant stabilizer, and multivibrator.
c. Multivibrator, blocking oscillator, and resonant stabilizer.
d. Step-counter, resonant stabilizer, and blocking oscillator.

30. (109) What are the four basic sections of the interlace sync generator shown in figure 32 of this text?

a. Master oscillator, HV mixer, 2:1 counter, and the 525:1 counter.
b. Master oscillator, blanking mixer, 7:1 counter, and the 5:1 counter.
c. Master oscillator, 7:1 counter, 5:1 counter, and the 3:1 counter.
d. Master oscillator, 15:1 counter, 7:1 counter, and the 2:1 counter.

31. (108) What are the three basic sections of a simple noninterlace sync generator?

a. Vertical oscillator, horizontal oscillator, and sync separator.
b. Vertical oscillator, 31.5-kc oscillator, and vertical drive.
c. Vertical oscillator, horizontal oscillator, and blanking mixer.
d. Vertical oscillator, horizontal drive, and blanking mixer.

32. (108) In what section of a simple noninterlace sync generator are height adjustments generally accomplished?

a. Vertical blanking section.
b. Horizontal oscillator section.
c. Vertical drive section.
d. Vertical oscillator section.

33. (108) In the multipulse sync generator shown in figure 30 of the text, in what circuits are pulse width and amplitude adjustments normally accomplished?

a. Squarer and peaker circuits.
b. Clipper and shaping circuits.

c. Blanking mixer. squarer and peaker circuits.
d. Blanking mixer. clipper and shaping circuits.

CHAPTER 4

34. (113) What type video amplifier is used at junction points in a closed-circuit TV distribution system?

a. Isolation.
b. Parametric.
c. Picture signal.
d. Pulse.

35. (113) Which of the following will broaden the low- and high-frequency video bandpass of a video amplifier?

a. A decrease in the load impedance.
b. Degenerative feedback.
c. Series and shunt peaking.
d. An increase in the load impedance.

36. (112) If the camera control scene appears more gray than white, which control should be adjusted first?

a. Horizontal shading.
b. Black stretch.
c. White stretch.
d. Gray scale gain.

37. (113) An advantage of transistors as compared to tubes for use in video amplifiers is that transistors

a. give more gain per stage.
b. have lower noise figures.
c. are more adaptable to compensation.
d. are more adaptable to direct coupling.

38. (112) How do the shading signals which are added at the video amplifier (camera control unit) compensate for previously inserted horizontal and vertical shading?

a. They cancel any spurious shading signals which may still be present.
b. They increase the amplitude of the horizontal and vertical pulse amplifiers.
c. They cancel a portion of the blanking signal.
d. They reenforce the action of the damper circuits.

39. (111) Which of the following *best describes* the function of the multistage multiplier within the image orithicon tube?

a. To increase the intensity of the emitted electron beam.
b. To control the position of the emitted electron beam.
c. To increase the output current of the tube.
d. To control secondary emission from the photocathode.

40. (112) Which of the following is *not* a function of the image orthicon camera control?

a. To correct for shading.
b. To adjust for proper blanking and black level.
c. To correct for black and white compression.
d. To preamplify the signal from the target image.

41. (111) If an image burn appears on the target screen of an image orthican tube. which of the following is a likely cause?

a. The target is being underscanned.
b. The target is being overscanned.
c. The alignment coil current is excessive.
d. The image accelerator voltage is excessive.

42. (111) What is one purpose of the video output stage shown in the block diagram of the vidicon TV camera in figure 43 of the text?

a. To amplify the output signal.
b. To develop a signal which may be monitored at Tp 3.
c. To superimpose the picture information onto the horizontal and vertical blanking pulses.
d. To minimize loading effects.

43. (112) In figure 50 of the text, a program output can be achieved and yet keep the two fader channels available for previewing, etc., by using the

a. monitor switch.
b. program transfer switch.
c. sync input relay.
d. alternate channel switches.

44. (111) The electron gun of a vidicon camera is made up of which of the following?

    a. Heater, cathode, control grid, accelerating grid, and shaping grids.
    b. Heater, cathode, control grid, and focusing coil.
    c. Heater, cathode, control grid, shaping grids, and deflection coil.
    d. Cathode, control grid, shaping grids, and a permanent magnet.

45. (111) If a horizontal straight line appears on the viewfinder of an image orthicon camera, what is a likely cause?

    a. Blanking output stage is inoperative.
    b. Horizontal damper is inoperative.
    c. Vertical sawtooth generator is inoperative.
    d. Horizontal sawtooth generator receives no input.

46. (111) Into which three sections is the image orthicon tube divided?

    a. Scan, focus, and deflection.
    b. Multiplier, scanning, and image.
    c. Image, focus, and multiplier.
    d. Lens, scanning, and multiplier.

47. (111) Which is an indication that the beam control of a vidicon tube is critically adjusted?

    a. Small specks in the mosaic.
    b. An illuminated screen.
    c. A single vertical line.
    d. A single horizontal line.

48. (111) How may image burn damage to the photoconductive faceplate of the vidicon tube be prevented?

    a. By focusing the camera on a fixed spot of high intensity light.
    b. By adjusting the camera scan to utilize the maximum area of the faceplate.
    c. By adjusting for maximum vertical scan after making all other adjustments.
    d. By mounting the tube so that sunlight strikes the faceplate at a downward angle.

49. (111) If, after a 10- to 20-minute warmup period, there is no visible display on the screen of a vidicon tube, which adjustment should be made first?

    a. Centering.
    b. Vertical.
    c. Camera scan.
    d. Beam control.

50. (111) Which of the following statements concerning vidicon cameras is true?

    a. A scanning beam is produced by the electron gun.
    b. Alignment is accomplished by a synchronizing pulse.
    c. Signal output is taken from the cathode circuit.
    d. Focus is accomplished by the accelerating and shaping grids.

CHAPTER 5

51. (115) What is faulty if the display on a kinescope has a black top half and a white bottom half?

    a. HV supply.
    b. Kinescope.
    c. Horizontal oscillator.
    d. Vertical oscillator.

52. (114) A width control is *not* included in the monitor schematic shown in figure 60 of the text because

    a. it would adversely affect the sync separator stage.
    b. the H-hold control changes the horizontal width.
    c. it would cause horizontal overscan of the display.
    d. it would alter the horizontal output signals.

53. (114) Why is a combination monitor used in conjunction with the camera control unit?

    a. It has a large screen picture display.
    b. It provides for signal and picture analysis.
    c. It controls all other monitors in the system.
    d. It controls the outputs from the camera control unit.

54. (114) From what stage does the sync amplifier of a utility monitor receive its input?

    a. Video input amplifier.
    b. Video output amplifier.
    c. Sync separator.
    d. Phase detector.

55. (115) What are two noteworthy features that commonly distinguish a master monitor from other types of monitors?

   a. Direct horizontal frequency control and a separate HV supply.
   b. Horizontal afc and numerous video amplifiers.
   c. D-c restoration and numerous video amplifiers.
   d. Sync separation and d-c restoration.

56. (115) If *no* raster appears on the kinescope of a master monitor, the failure of what section will cause this?

   a. Horizontal section.
   b. Vertical section.
   c. HV supply section.
   d. Video section.

57. (114) For the TV monitor shown in figure 60 of the text, the vertical oscillator is adjusted for proper synchronization by changing the

   a. bias on Q6 with the height control.
   b. bias on Q5 with the height control.
   c. bias on Q6 with the linearity control.
   d. cutoff time of Q5 with the V-hold control.

CHAPTER 6

58. (116) To mechanically adjust two polydirectional microphones—one to pick up all classroom sound and the other to pick up, primarily, the instructor, you would adjust

   a. both microphones for unidirectional pickup.
   b. both microphones for nondirectional pickup.
   c. one microphone for unidirectional pickup and the other for nondirectional pickup.
   d. both microphones for bidirectional pickup.

59. (119) Where would be a likely place to first check for a hum which is reported on all monitors?

   a. All microphone cables and connectors.
   b. All preamps and mixer controls.
   c. Each cable and switch to the monitors.
   d. The hum balance in the power supply.

60. (118) The audio console

   a. amplifies, switches, and mixes audio.
   b. amplifies, switches, and detects audio.
   c. switches, mixes, and detects audio.
   d. switches, mixes, and multiplexes audio.

61. (117) Which transistor amplifier configuration can develop the greatest power gain for a given transistor?

   a. CB.
   b. CC.
   c. RC.
   d. CE.

62. (119) Which of the following would be the correct signal path through an audio control console?

   a. Microphone, program amplifier, preamp, output, and VU meter.
   b. Microphone, preamp, program amplifier, and output.
   c. Microphone, VU meter, program amplifier, preamp, and output.
   d. Program amplifier, VU meter, preamp, and output.

63. (116) The capacitor microphone operates with

   a. two electrodes and a variable capacitance.
   b. two electrodes and a fixed capacitance.
   c. three electrodes and a fixed capacitance.
   d. three electrodes and a variable capacitance.

64. (116) Which type of microphone uses the "sound cell" to produce an a-c signal?

   a. Dynamic.
   b. Carbon.
   c. Crystal.
   d. Capacitor.

65. (116) Which of the following microphone types has the *best* frequency response?

   a. Carbon (double-button).
   b. Dynamic (moving-coil).
   c. Crystal.
   d. Capacitor.

66. (116) What are the *most widely* used types of microphones?

   a. Dynamic, carbon, crystal, and ribbon.
   b. Dynamic, carbon, crystal, and moving coil.
   c. Carbon, crystal, moving coil, and variable resistance.
   d. Dynamic, crystal, capacitor, and carbon.

67. (116) Which statement *best describes* the dynamic microphone?

a. It generates a-c by movement of a diaphragm which flexes a bimorph unit.
b. A diaphragm moves a coil of wire between the poles of a magnet.
c. It generates a-c by using two flexing electrodes.
d. It has a moving carbon pile in a magnetic field.

CHAPTER 7

68. (123) In a color monitor, why is one output from the 3.58-mc oscillator delayed 90°?

a. So the Y signal will reach the matrix at the proper time.
b. Because both +I and −I signals are needed in the matrix.
c. To obtain the Q signal from the chrominance signal.
d. This is necessary to accomplish afc for the oscillator.

69. (121) In which section of a color camera chain are the color signals modified to produce the proper luminance variations?

a. Sync generator.
b. Colorplexer.
c. Processing amplifier.
d. Camera control.

70. (121) In which ways do the preamps used in a color camera differ from the preamp used in a monochrome camera?

a. Preamps used for color have high-frequency peaking adjustments.
b. Preamps used for color have low-frequency adjustments.
c. A monochrome preamp has both high- and low-frequency adjustments.
d. The color preamps have both high- and low-frequency adjustments.

71. (123) What outputs from the matrix of a color monitor are usually used for color temperature adjustment?

a. B and G.
b. B and R.
c. I and Q.
d. Y and R.

72. (120) The Y signal has the same bandwidth as which of the following signals?

a. Modulated I.
b. Modulated Q.
c. Chrominance.
d. Monochrome.

73. (123) Which stage is necessary for both single-input and three-input color monitors?

a. Color killer.
b. Sync separator.
c. Phase detector.
d. Matrix.

74. (123) Which condition normally causes the color killer to cut off the bandpass amplifier?

a. No color burst sync.
b. No input to the phase detector.
c. No luminance signal received.
d. No 3.58-mc oscillator output.

75. (122) What does the burst flag pulse control?

a. Duration of the color sync.
b. Frequency of the color carrier.
c. Width of the back porch.
d. Compatibility with monochrome.

76. (121) Color TV cameras differ from monochrome TV cameras in that they are

a. smaller, less sensitive to light, and have three pickup tubes.
b. larger, have a different optical system, and have three pickup tubes.
c. larger, have no drive system, and have four pickup tubes.
d. smaller, have a different drive system, and a different optical system.

77. (121) Which of the following purposes is accomplished by the mirror arrangements of color TV cameras?

a. They prevent image burn of the green camera tube.
b. They prevent image burn of the red camera tube.
c. They divide the light image into color groups.
d. They shift the image slightly to prevent burning of the monochrome camera tube.

78. (120) Why are blue, green, and red used as the primaries in color TV?

a. They are good absorbers of color light.
b. They are the only additive primaries.
c. They are sensed equally by the eye.
d. They produce the greatest variations of color.

79. (120) What size images would be affected if the Q information in a color signal was *incorrect*?

a. Large.
b. Medium.
c. Small.
d. All.

80. (120) What property of colored light describes the amount of white light mixed with a particular color?

a. Hue.
b. Saturation.
c. Luminance.
d. Brightness.

81. (120) What can be determined from a chromaticity diagram?

a. Hue and saturation.
b. Luminance and saturation.
c. Luminance and hue.
d. Compatibility and bandwidth.

82. (120) Which signal contains the 3.58-mc color carrier reference?

a. Chrominance.
b. Luminance.
c. Modulated Q.
d. Composite color.

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CDC 30455

TELEVISION EQUIPMENT REPAIRMAN

(AFSC 30455)

Volume 2

Auxiliary Equipments

Extension Course Institute

Air University

Preface

TELEVISION is no spontaneous presentation; it is a combined operation. The video mosaic which appears on the monitor screen is the result of many skills, much planning, accurate timing, and sometimes artistry. In this course we view this complicated system of communications as it concerns the television repairman and technician.

This volume is the second of a three-volume course. In Volume 1 we discussed equipment and maintenance requirements of the basic elements of a television system: image pickup devices at the point of origin, the means of transmitting closed-circuit electrical signals to the intended receiving locations, and the facilities for converting the signals to reproduce the images for the viewer. In Volume 2 we will discuss the maintenance requirements and operation of additional equipment required to support various functions of the television systems. Included in this discussion are the equipment for studio lighting systems, intercom facilities, special effects, prompting facilities, audio and video recording systems, as well as specialized equipment required for maintaining television equipment. A discussion of relay equipment in addition to television VHF and UHF transmitters, receivers, antennas, and associated circuitry is also presented in this volume.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to Tech Tng Cen (TSOC), Keesler AFB MS 39534.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development, Study Reference Guides, Chapter Review Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If he can't answer your questions, send them to ECI, Gunter AFB AL 36114, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 30 hours (10 points).

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CHAPTER 1

Studio and Control Equipment

SINCE STUDIO lighting affects the performance of the camera, lighting is an important factor in lens selection. In this chapter we discuss lighting prior to describing various types of auxiliary studio equipment and their maintenance, and later on, discuss the TV prompter, rear screen projector, and special effects equipment. Representative distinctive circuits are analyzed because these circuits are required for the special effects generator and amplifier. We also discuss essential functions and how they are accomplished by this equipment. Finally, we discuss intercom systems that may be used for TV.

1. Studio Lighting

1-1. Illumination of the studio set plays an important part in obtaining the best results from a TV camera. Since you as a maintenance man need to understand the effect of light on camera operation, you should know the language of lighting. You should also know how to obtain suitable illumination through the use of various types of lighting. With your knowledge of quality, intensity, levels, and sources of light, you can select lenses and make adjustments with facility and intelligence.

1-2. **Terms.** The following terms are generally accepted and are becoming standard throughout the television and motion picture industry. These terms are generally used for describing studio set-lighting layouts and for articles describing lighting layouts.

1-3. **Base Ligh[illegible]g.** Base lighting is the uniform diffused illumination (approaching a shadowless condition) which covers an entire set. It is often supplemented by other lighting, such as key and fill lighting. The intensity of base lighting depends upon the sensitivity of the TV equipment being used; that is, the amount of light necessary to provide a picture of technical acceptability. Because base light is a well-diffused light, we know that it must be provided by either incandescent floodlights or flourescent lights.

1-4. **Key Lighting.** Key lighting is provided by the principal source of directional illumination falling upon a subject or area. This may be natural light coming through a window or open door, from a fireplace, or another source; or it may be artificial light coming from spotlights with special accessories. Key lighting is sometimes divided into two groups—high-key and low-key lighting—in order to facilitate discussion of scene illumination, with respect to a gray scale of TV. High-key lighting usually results in a picture having graduations falling primarily between gray and white, with dark grays and black present in very limited areas. Low-key lighting, on the other hand, results in a picture having graduations from middle gray to black, with limited areas of light grays and white.

1-5. **Fill Lighting.** Fill lighting is the supplementary illumination of portions of a scene or set to control shadow or contrast. Fill light is some type of diffused light, supplied by any of a number of sources. For example, fill light would illuminate the opposite side of a key-lighted subject, thus bringing out the details which otherwise would have been lost.

1-6. **Effects Lighting.** Effects lighting is illumination resulting in the simulation of special effects such as firelight, clouds, or window light. This type of lighting may be used to simulate flashes of light from explosions, for example, in making military training lessons. Among other studio aids which we will study in the following section are rear screen projectors, which are sometimes used to produce effects lighting.

1-7. **Other Lighting.** There are a number of designations given to lights used for a specific purpose. These would include cross, back, side, eye, and set lights, which are used as indicated by the name. It is necessary for the maintenance man to be aware of the usage of these lights, in anticipation of limited maintenance. This maintenance will be determined in most cases by the extent of light used by the production agency.

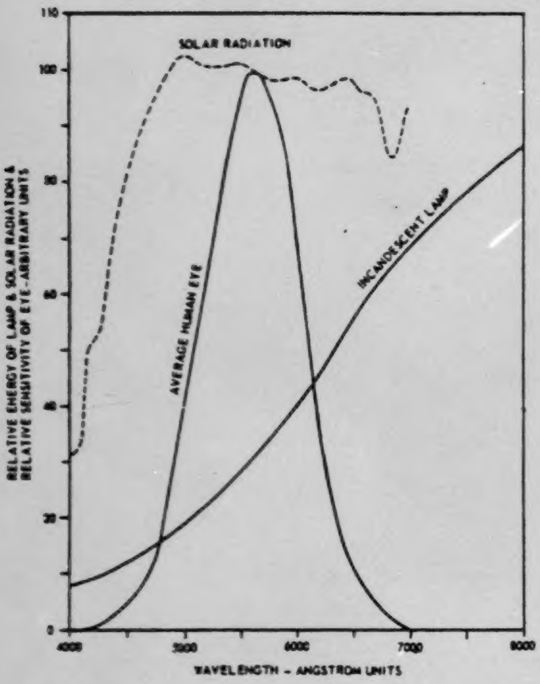

Figure 1. Relative light energy.

1-8. **Requirements.** The requirements for good light are directly related to the quality of the desired television image. In some instances the available light can be controlled, while in others it cannot. If the light is to be controlled, the maintenance man will set up his TV equipment accordingly; if uncontrolled light is to be used, the optimum performance settings must be adjusted to average light conditions.

1-9. It is known that spectral characteristics of a light source should be compatible with those the camera pickup tube used and be psychologically suited to the personnel in the studio. Figure 1 shows the relative characteristics of several light sources. The first curve (dashed line) represents the energy from solar radiation. Note that this curve is relatively flat and approaches white light (which contains all frequencies).

1-10. The second curve shows the relative energy from a typical incandescent light source. Most of its energy falls in the red region (6000 to 8000 angstroms). For this reason, incandescent lamps appear yellow or slightly red to the human eye. The response of the human eye to any light source is determined by the relative sensitivity of the human eye as represented by the third curve in figure 1.

1-11. In Volume 1 you learned that both the image orthicon and the vidicon have response curves closely resembling the sensitivity curve of the eye. Although both tubes will perform satisfactorily as pickup tubes, they are sensitive to light levels. The spectrum of light is good for both; but, as you know, the image orthicon is much more sensitive than the vidicon. Minimum lighting level for producing good pictures lies between 32 and 64 footcandles with an f:8 lens. The average TV installation should be capable of producing 200 footcandles of illumination on any given scene to permit flexibility in the control of lighting and lens stops.

1-12. Again referring to figure 1, we see that where the energy of the incandescent lamp is weakest the sensitivity of the eye is strongest. Since the sensitivity of camera tubes and the eye compare favorably, we can assume that the incandescent lamp is a good light source for TV. Fluorescent lighting is weak in the red regions; therefore, skin tones appear darker. It is for this reason that fill or key light of an incandescent source must be used with fluorescent lighting. This knowledge of proper lighting techniques is important to the maintenance man making camera adjustments.

1-13. **Equipment Types.** The control of light intensity usually requires more than turning lights off and on in a studio area. Auxiliary equipment is required to produce the types of lighting we have discussed and to meet the requirements of good lighting. Some studios are equipped with a control center containing master switches, branch circuit switches, group dimmer controls, and individual dimmers to aid in control of the lighting. As an additional aid in the achievement of good lighting, patching facilities may be included. Their addition permits the patching of dimmers and switches into various circuits to control illumination at different points with a minimum of equipment. For convenience and to increase versatility, equipment which permits horizontal and vertical movement of lighting fixtures is usually provided.

1-14. You must realize that there may be studio operations where the lighting is maintained by a section other than the TV maintenance section. However, since lighting is sometimes maintained by the TV maintenance section, it is important that you know the lighting requirements and are prepared to perform maintenance if necessary. Some of the generally preferred light sources are incandescent, fluorescent, and mercury-vapor lamps. The most widely used is the incandescent source and it is grouped into the following types: floodlights, spotlights, strip lights, and effects lights.

1-15. Floodlights are those used to give a wide-angle general illumination or base lighting. An incandescent floodlight consists of a lamp socket, lamp, reflector, and diffuser lens. The device may be any size from 10 to 18 inches in diameter and have lamps varying from 500 to 2000 watts. The maintenance of this type of floodlight will probably consist of lamp replacement or wiring repair. An important part of this type of maintenance is the exact replacement since equipment is set up for a given light level. If a different wattage lamp or a different size or type of reflector were substituted, the equipment would have to be adjusted accordingly. Sometimes fluorescent floodlights are used if light manipulation or control is not a significant factor. However, because of the weakness of fluorescent light in the red regions, there should always be some incandescent lighting.

1-16. Spotlights come in a wide variety of sizes (from 3 to 16 inches in diameter) and use incandescent lamps ranging from 75 to 5000 watts. Spotlights also may have specially shaped reflectors to direct the light beam into a designated geometric pattern. For additional pattern control, some spotlights have iris and shutter facilities which can be adjusted. In all instances, it is important that during maintenance only exact replacements are made due to light level requirements.

1-17. Strip lights are useful in background lighting, as base lighting, top lighting, or fill lighting. In some applications, strip lights will function as floodlights for base lighting. At other times strip lights will fill the need for effects lights. Since all lighting directly affects image illumination as seen by the camera, repairs must be on an exact replacement basis to insure optimum operation of equipment.

1-18. Operational placement of lights and their controls normally is not the responsibility of the maintenance section. However, you should be aware of their placement during operation so that you can quickly make necessary repairs. If you are required to perform maintenance on controls and patch panels, you should be familiar with their location, function, and routine maintenance procedures.

1-19. **Lenses.** The average image orthicon camera pickup tube (reference Volume 1) requires a minimum light level of approximately 50 footcandles incident with a lens opening (stop) of f:8. The larger the "f" number of the lens setting, the less the amount of light that will reach the photocathode. The image orthicon tube does not have the same pickup quality as photographic film; lens openings as low as f:1.9 can be used but the technical quality will not be good. If a large amount of light is used or is present, the lens "f" number may be as high as f:16.

1-20. The TV camera uses lenses similar or identical to ordinary film camera lenses. These lenses are used to focus an image of the viewed scene upon the photosensitive element in the camera pickup tube. The image orthicon cameras generally use 35mm optics, while vidicon cameras use 16mm optics. The 16mm lenses for vidicon film cameras are usually of short focal lengths (approximately 3 inches). The 35mm lenses used on most field and studio cameras include closeup lenses with focal lengths from 35mm to 135mm, and middle to long distance lenses with focal lengths from 8½ inches to 25 inches.

1-21. Most studio and field cameras have a four-lens turret to accommodate a variety of lenses of different focal lengths. With the lenses preset, they may be switched by turning the lens turret. No adjustment is necessary. Most lenses have iris or diaphragm mechanisms built in which would be a part of the preset adjustments. A maintenance repairman will be concerned with the adjustments made during setup; from there on the adjustments are made by the camera operator. Otherwise, the chief concern of maintenance is the cleaning of the lenses and checking for any damage to optical or mechanical parts. Normally, there will be no repair—only removal and replacement.

1-22. An additional lens type is the zoom lens, which is a lens assembly of continuously variable focal length. There are a number of types of zoom lenses available and in use. Some of these types are quite simple and may be mounted on the lens turret in addition to standard lenses. Other versions of the lens are manually or electrically controlled and are the only lens on the camera; their mounting requires removal of the lens turret. Again, the maintenance of this lens is usually limited to cleaning or removal and replacement.

1-23. With the various lens configurations available, it is possible to make many choices of lens units. Normally you are not required to make this choice or selection as the equipment is equipped with a lens. It is important that you do not interchange lenses during cleaning, inspection, or other maintenance. For this reason, you must have a working knowledge of lenses.

2. Studio Aids

2-1. In this section we will discuss two basic groups of studio aids—TV prompters and rear screen projectors. The basic construction and maintenance requirements as well as some of the electrical circuits of a TV prompter will be considered. The rear screen projector portion will include the fundamental advantages and disadvantages in comparison with other types of pro-

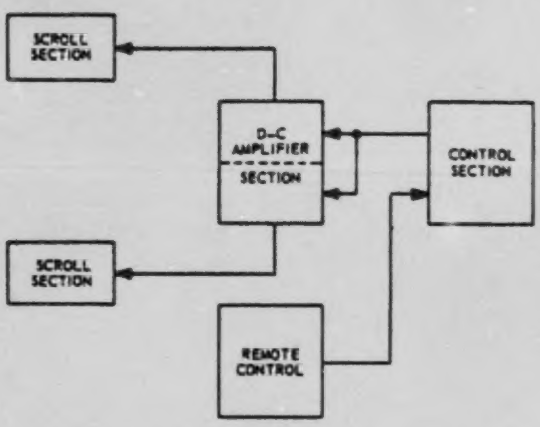

Figure 2. Block diagram of a basic TV prompting unit.

jectors. General construction, maintenance requirements, and repair features of both groups will also be developed in this section.

2-2. **TV Prompter.** TV prompting is any verbal or visual means of supporting program scripts. Verbal prompts are usually given by a script-following prompter near the speaker. Examples of visual prompting devices are cue cards, front and rear screen projectors, semitransparent mirrors, and roll or scroll type equipment. In this discussion we are concerned with a typical roll or scroll type prompter which, unseen by the audience, unrolls a prepared script, line by line, to aid the speaker.

2-3. A typical scroll TV prompter can be considered as a single unit containing several sections. Figure 2 illustrates the sections and the relationship between them. The scroll section contains a d-c motor, a gear train, two reels, and the paper upon which the information is printed. This section is usually mounted on or near a television camera with each camera having its own scroll section. The control section is comprised of a power supply, control circuits, and synchronizing circuits. The d-c amplifiers constitute a separate section which feeds the scroll motors. The amplifier section contains two identical circuits, each one of which controls an individual scroll. The speed and forward-reverse controls are located in the remote control section.

2-4. *Circuit analysis.* The circuit diagram, shown in figure 3, illustrates the basic electronic functions of a prompting unit, with the exception of the power supply. The bleeder, R1, R2, R3, and R4, serves as a voltage divider network incorporating potentiometer R2. Note that the bleeder network is tapped at two different points. A portion of the d-c voltage is selected at point R2 and applied, through resistors R5 and R6, to the grids of V1 and V2, respectively. The tap between resistors R3 and R4 supplies the operating voltage for relay K1. Both switch S1 and relay K1 are shown in their normal (open) positions. When S1 is closed, a d-c voltage is applied to one set of the coil windings for K1 and the relay energizes (S1 also controls the relay for the other motor). With B+ present at the center contact of K1 and the movable contacts pulled up, B+ is applied (through the windings of motor M1) to the plate of V1. Amplifier V1 then conducts and current flows through the windings of the motor, causing the motor to run in the forward direction. The motor is reversed by simply placing switch S1 in the other ON position, thus applying voltage to the other set of windings K1. This causes K1 to energize, the movable contacts to be pulled down, and B+ to be applied (through the wind-

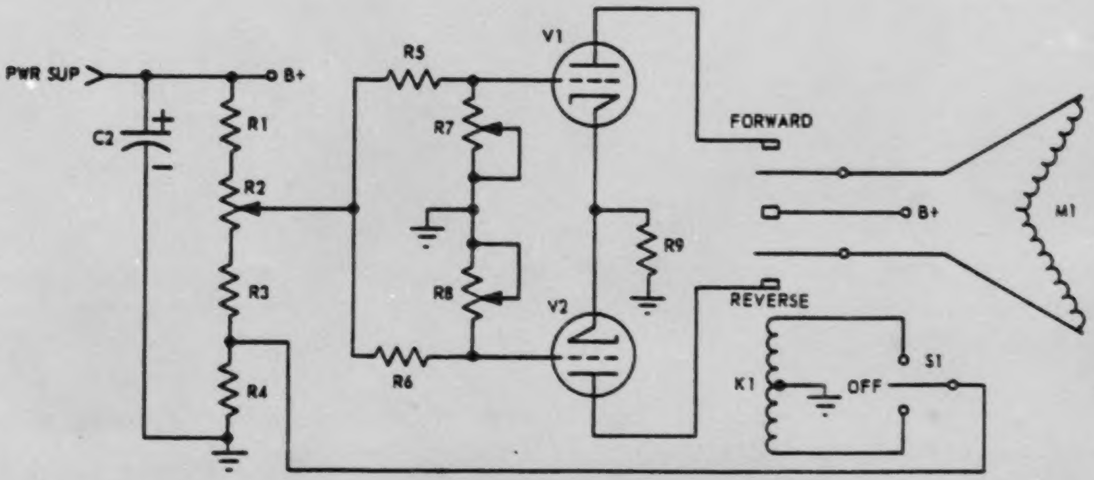

Figure 3. Diagram of amplifier and control circuits of a basic TV prompter.

ings of motor M1) to the plate of amplifier V2. Amplifier V2 then conducts and current flows through the windings of motor M1 in the opposite direction, thus reversing the motor. The motor speed is varied by adjusting R2 which varies the amount of voltage applied to the amplifier grids (R2 also controls the other scroll motor). Resistors R7 and R8 are balance controls and are necessary for adjusting the individual motor speeds (forward and reverse). A start-stop system (not shown), initiated by the script paper, provides for synchronizing the scroll motors.

2-5. *Maintenance requirements.* The TV prompter maintenance requirements include cleaning and inspecting the prompter and replacing damaged or broken components. All interconnecting cables and connectors must be inspected periodically to insure that there are no broken connections. Periodic inspection and cleaning of the synchronous motors and gear trains is necessary to prevent binding and sluggish movement. The relay contacts must also be cleaned at periodic intervals to prevent arcing, sticking, poor connection between contacts, or other undesirable effects.

2-6. *Troubleshooting and repair.* Troubleshooting the TV prompter unit is comparatively simple. The most frequent malfunctions occur in tubes, fuses, cables, and cable connectors. For example, you find that the motor runs at a normal forward speed, but runs very slowly in reverse with minor speed variations when the balance control is adjusted. A possible cause of the trouble is a weak amplifier tube in the reverse circuit. If, on the other hand, the motor runs very slowly in either direction, the probable cause is a sluggish gear train.

2-7. **Rear Screen Projection Methods.** Several types of rear screen projectors and projection methods are employed in television production. You, as a maintenance technician, must be familiar with the varied types of equipment and the requirements necessary for normal operation of this equipment. In many instances the familiar 35mm slide projector, with increased lighting, may be used to satisfy the rear screen projection requirements. With this in mind, we will explain the basic operation and variations employed in rear screen projectors.

2-8. *Stages.* The stage of a projector is that portion of it upon which the object is positioned for display. A stage may be either vertical, horizontal, or a combination of both (see fig. 4). Though much of the projection is accomplished

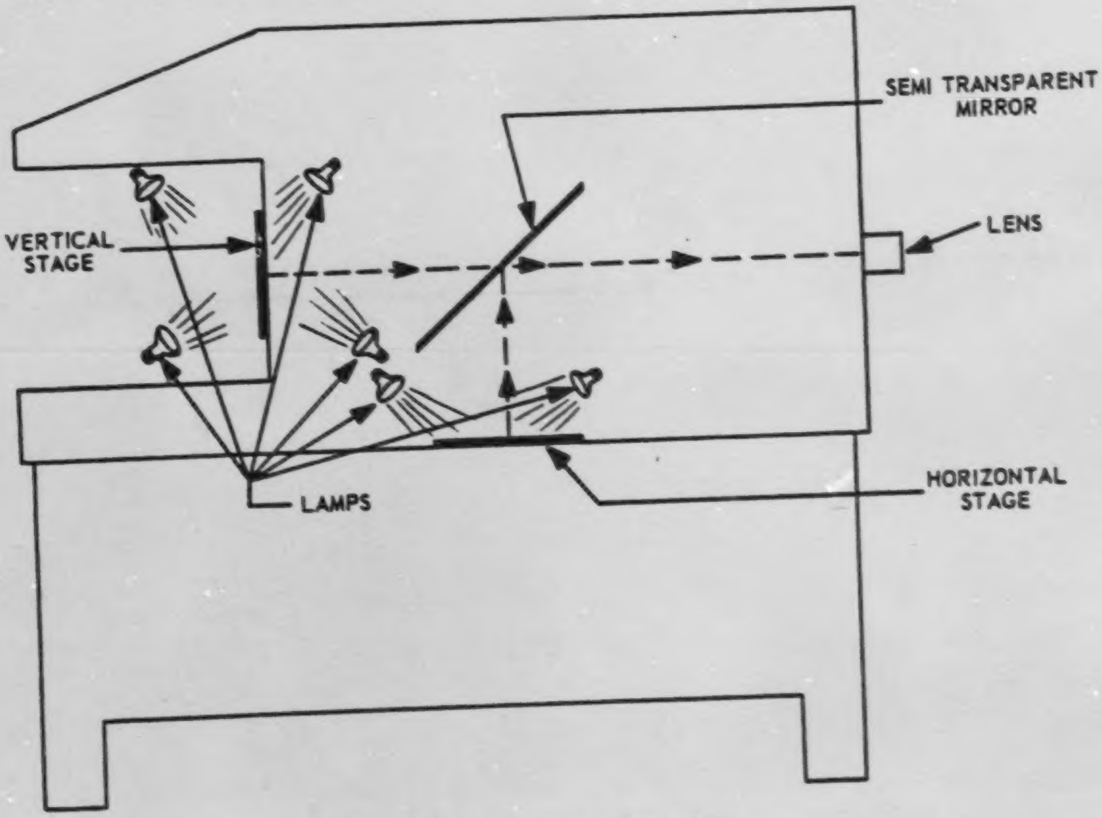

Figure 4. Basic rear screen projector.

by the use of transparencies, other items such as opaque objects or photographs may be projected. When an opaque object is projected, the horizontal stage is obviously preferable to a vertical stage; the object could simply be placed upon the stage. On the other hand, a vertical stage is useful when projecting a transparency or photograph.

2-9. *Mirrors.* Mirror action is governed by two laws of reflection. The first law simply states that the angle of incidence is always equal to the angle of reflection. In other words, light rays bounce off the mirror surface at the same angle with which they strike it. This angle is measured from the normal or perpendicular to the mirror surface. The second law states that the incident, reflected, and normal rays lie in the same plane. An understanding of these two laws is necessary for alignment of projector mirrors. Figure 5 illustrates these laws.

2-10. Semitransparent mirrors are frequently used in rear screen projectors and are sometimes referred to as half-silvered mirrors. Mirrors of this type have the property of reflecting from the lighted side and at the same time being transparent from the dark side. When both stages in figure 4 are lighted, the two displays are superimposed. The use of this particular type of mirror facilitates certain projection techniques: the image from one stage can be deflected through the lens; also, the image from a second stage can be projected through the mirror into the same lens. The most important disadvantage of this type of mirror is its light absorption characteristics. Semitransparent mirrors are not very efficient since 30 percent of the light delivered is not reflected or transmitted but is absorbed by the glass and silver coating.

2-11. Depending upon design features, combinations of front surface and semitransparent mirrors may be contained in rear screen projection equipment. Care must be exercised to insure that all reflected images will be projected along approximately the same optical axis. If the images are not projected on nearly the same optical axis, keystone effect will occur. Figure 4 is an example of a more simplified projector using a single semitransparent mirror to permit operation from one of either of the two stages. Note that the mirror is so aligned as to project the image from either stage along the same optical axis.

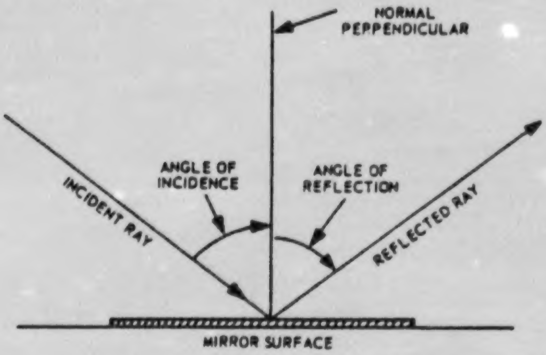

Figure 5. Law of reflection—angle of incidence equals angle of reflection.

2-12. *Lenses.* The physical assembly of lenses designed for projection machines differs from those designed for camera operation. Projection lenses are less complicated due to the fact that they are required only to change the focal distance of the projected image. Unlike camera lenses, they are not required to control the quantity of light from the projection machine.

2-13. *Lighting.* Lighting methods for the projection of opaque objects and photographs differ from those used for transparencies. The lights are placed in front of the stage for opaque objects and photographs, and behind the stage when transparencies are used. An example of light placement is shown in figure 4.

2-14. The light necessary for rear screen projection is much greater than for front screen projection. A front screen projector, for example, requires only 100 watts to project a 6- × 9-foot image, whereas a rear screen projector needs 1000 watts to project a picture of the same size. Depending upon the studio lighting, a typical rear screen projector will require more or less light energy to cover the projection screen without noticeable fall-off of intensity around the edges of the screen. The best general rule to follow is to place the subject to be viewed in the projector and adjust the lighting for the best picture. The exact amount of illumination will depend on how much front lighting is used on the projection screen, density of the transparency, type of scene being projected, screen size, and degree of light fall-off. Studio lighting sources must not be directed toward the projection screen. Fall-off and scene types will be included in the discussion of rear projection screens.

2-15. Some rear screen projectors, especially 16mm, employ carbon arc lights for illumination. Caution must be exercised when using this type of lighting due to the fumes emitted. Blowers and a venting system should be installed to carry the fumes from the immediate area.

2-16. Since rear screen projectors require a high light level for operation, blowers are installed to provide the necessary cooling. Cooling the equipment also helps to prevent damage to the object being projected.

2-17. *Other features.* Many other features can be incorporated in the rear screen projector which would facilitate a more complete operational capability. Such features as individual light switches, dimmer, and iris controls will improve the flexibility of the rear screen projector. More complex equipment may also contain both vertical and horizontal crawl mechanisms—a means of moving a film strip across the stage at an even rate of speed.

2-18. Some means of wiping an image can be employed when using even the simplest of projectors. Wiping is the process of removing or erasing all or a portion of one display—often accomplished with another display. An image may be wiped either vertically, horizontally, diagonally, or by any combination of these. If the wiping action is accomplished vertically, the new display will enter either from the right or left. Horizontal wiping is done with the new display entering from the top or bottom of the original picture.

2-19. *Screens.* Commercially produced rear projection screens are expensive and unnecessary when fall-off is not a problem. Many other materials are more readily available and are adequate under certain circumstances. Tracing paper, cloth, oiled canvas, white Koroseal, and white latex are some common materials that can be purchased from local outlets. Some consideration must be given to the size of the picture to be projected since a small picture will show the material grain, thus destroying much of the picture quality.

2-20. The projection screen must be designed so that it will diffuse light and still permit the image to project through it. Since a clear screen allows light to pass directly through it, the camera sees only a point of light. This point of light is referred to as a "hot spot." Because projection screens cannot be designed to diffuse light proportionally in all directions, light intensity decreases from the center toward the outer edges. This characteristic is called fall-off.

2-21. Two intrinsic properties to be considered in selecting a projection screen are its light absorption and reflection characteristics. Both of these properties affect the reproduction of dark scenes since the ability of the projection screen to reproduce dark scenes depends upon the natural tone of the screen when the projector is turned off. The white projection screen reflects much light and absorbs very little light; therefore, its darkest tone is milkish gray. In contrast, a black projection screen gives excellent dark tone reproduction; however, it has such a high absorption factor that fall-off is rapid and noticeably distracting to a viewer. Thus, both white and black screens have disadvantages. A compromise, however, has been reached with the development of the blue projection screen. While it absorbs much of the reflected light, the blue screen does provide a good response with regard to fall-off.

2-22. *Maintenance requirements.* Rear screen projectors require only minor maintenance; cleaning and inspection will suffice in most instances. Projectors employing blowers and similar moving parts require lubrication at periodic intervals. Alignment of projectors must be considered on an individual basis. Equipment design and application are two principal factors determining the extent and types of maintenance required.

2-23. Cleaning of the mirror and lens surfaces is of great importance because dirt and smudges decrease their operating efficiency. Caution must be exercised when performing these tasks. A nonabrasive lens tissue and approved liquid lens cleaner are recommended for use on the mirror, lens, and other glass surfaces. Other types of cleaning material should not be used since any scratches or marks on these surfaces would cause permanent damage and decrease the efficiency of the mirror and lens components.

2-24. Lamps should be checked periodically and any cloudy bulbs replaced. Cloudy bulbs produce less light, thus decreasing the operating capabilities of the projector. Maintaining time logs on the projector lamps aids in determining bulb life. Changing bulbs within their expected life period reduces the possibility of equipment failure during operation.

2-25. There are three important factors when aligning a rear screen projector: (1) stability of projector base, (2) centering relationship between the projector and projection screen, and (3) angular relationship between the projector and projection screen. Because the slightest movement of the projector will be amplified on the projection screen, the projector must be placed upon a solid base. To permit clear focusing of the display over the entire screen, the projector must be centered in relation to the projection screen. To prevent keystone effect, all projections must be perpendicular to the projection screen.

2-26. *Troubleshooting and repair.* Rear screen projectors are simple to troubleshoot and repair compared to other equipment in a TV system. Most of the repair is confined to the replacement of broken mirrors, fuses, projection bulbs, defective power cords, and other similar items. When peculiar problems are encountered, the maintenance instructions for that particular projector should be consulted.

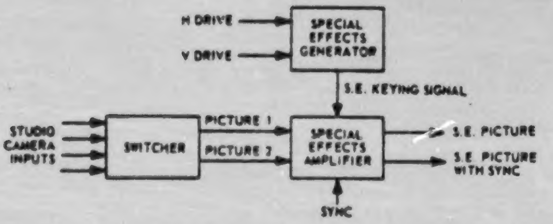

Figure 6. Relationship of special effects equipment showing essential inputs and outputs.

2-27. Let us, however, consider some examples of troubleshooting and repair. If a low level of illumination of the projected image were discovered during operation and it is judged to be common from more than one stage, a likely cause is either dirty mirrors or a dirty projection lens. Should the problem be evident from only one stage, the probable cause is a cloudy lamp. In either instance correction is quite simple. If the first example proves to be true, cleaning the lens and mirrors will eliminate the difficulty. Replacement of the lamp in the second example will rectify the problem. These are two examples of the most common troubles encountered in rear screen projectors.

3. Special Effects Equipment

3-1. A multitude of special effects and patterns can be achieved electronically as well as mechanically. Our concern will be with those electronically produced by auxiliary studio equipment—i.e., the special effects generator and the special effects amplifier. The effects amplifier, which receives two picture signals, combines the picture signals into a montage display that is determined by the keying signal. Although the keying signal can be obtained from a third camera, the special effects generator is advantageous when versatility and convenience are important. Figure 6 illustrates the relationship of the special effects equipment to each other and to a switcher. Note the inputs and outputs shown. The power supply (not shown) is generally a separate unit. It it a type of voltage regulated supply which you have studied previously in Volume 1, Chapter 2, of this course.

3-2. **Special Effects Generator.** A few special effects patterns are illustrated in figure 7. The small arrows indicate the direction of the wipe. Two pictures can be presented and wiped in a wide variety of ways with different keying signals produced by the special effects generator. The keying signal needed for a particular pattern is obtained by activating a regenerative clipper circuit with different waveforms. To gain a knowledge of how this may be done, let's analyze the circuit shown in figure 8.

3-3. Perhpas you recognize this circuit since it is commonly used to obtain rapid switching action. Although we referred too it earlier as a regenerative clipper, it is also known as a Schmidt trigger circuit. We have shown a transistor version; its operation is essentially the same as a circuit incorporating tubes

3-4. We have chosen an input signal which is a sawtooth of constant peak-to-peak amplitude that is steadily rising. This type of input is obtained when a sawtooth of one frequency is superimposed (mixed) with a sawtooth of a much lower frequency. For example, a 15,750-cps sawtooth can be combined with a 60-cps sawtooth to produce an input similar to that illustrated. You should realize, however, that only a few cycles of the higher frequency are shown. Moreover, these cycles are not to scale for the frequencies cited. We have exaggerated the input change per cycle to emphasize the variation of pulse widths that results at the output. The action of the circuit is what you need to understand to appreciate how the various outputs are generated for keying.

3-5. Note in figure 8 that a dashed horizontal line is drawn through the input signal. We will consider this line a d-c reference, which is the cutoff bias (base-to-emitter) of transistor Q1 and is called the threshold potential. It is appropriately named because the circuit is activated each time this potential is crossed by the input signal.

3-6. The circuit is designed so that when Q1 is cut off, Q2 is at maximum conduction and vice versa. Assuming Q2 is cut off, the output is low ($-V_{cc}$) as illustrated at t_0. Thus Q1 is con-

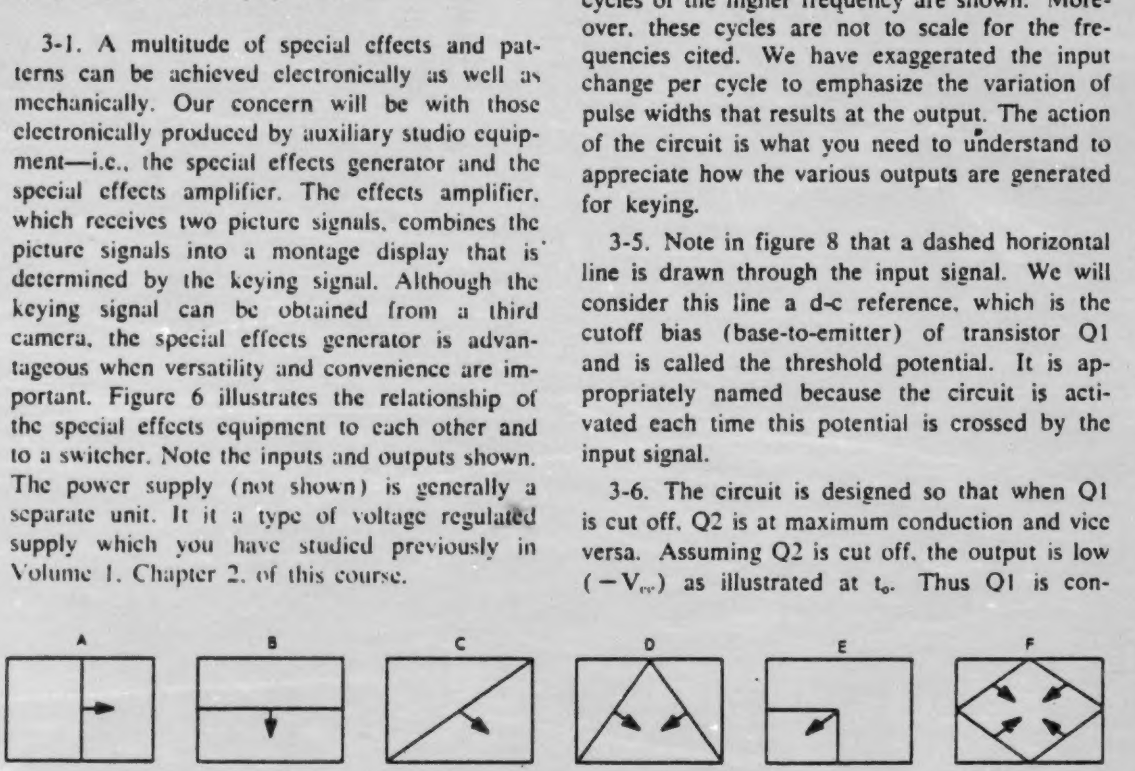

Figure 7. Special effects patterns.

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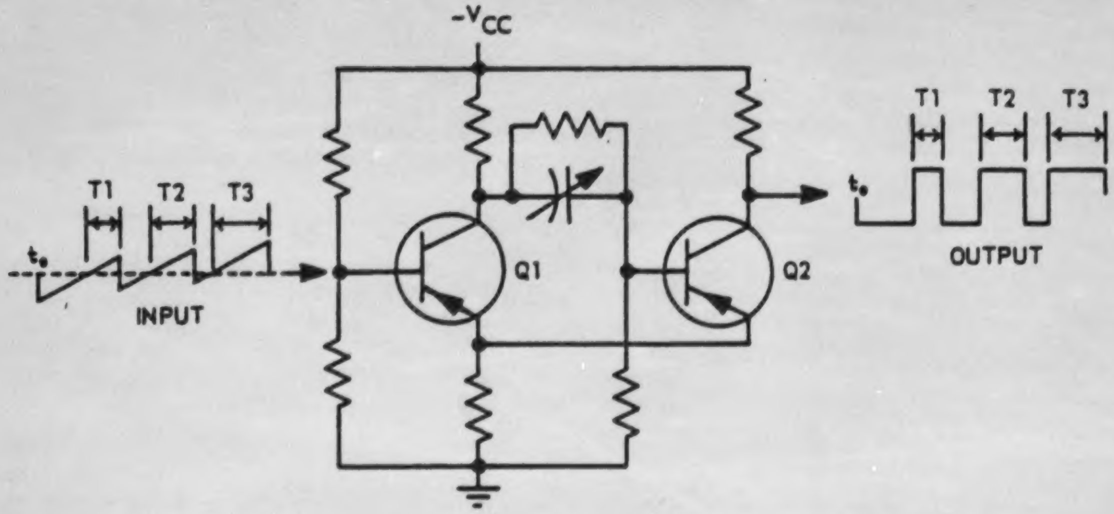

Figure 8. Regenerative clipper.

ducting and its collector potential is high (minimum negative). This condition will prevail until the input signal drives Q1 to cutoff. Observe that the input signal rises from time t_o and reaches the threshold potential at which time Q1 becomes cutoff. Its collector voltage goes to $-V_{cc}$ and a negative signal is instantaneously coupled to the base of Q2, driving Q2 into conduction. Because the emitter resistor is common to Q1 and Q2, a regenerative feedback occurs. The conduction of Q2 drives the emitter of Q1 more negative (further into cutoff). This action accounts for the rapid switching action that characterizes a regenerative clipper. The output switches from its low state to its high state as shown. During time interval T1, the output remains high. This interval is terminated when the input signal again crosses the threshold potential. Now, however, Q1 is driven into conduction, Q2 is cut off, and the output goes low again.

3-7. The output changes from one stable state to another every time the input crosses the threshold potential. In other words, the circuit is basically a triggered, bistable multivibrator. By causing the input sawtooth to rise steadily, the pulse width of the high-level output progressively increases. Notice that interval T2 is greater than T1 and that T3 is greater than T2. Likewise, note that the pulse width of the low-level output decreases proportionally since the input sawtooth frequency is constant.

3-8. Figure 9.A. shows the special effects pattern produced when a 15,750-cps sawtooth and 60-cps sawtooth are combined to drive the regenerative clipper. This diagonal pattern displays two pictures (identified as 1 and 2 in the

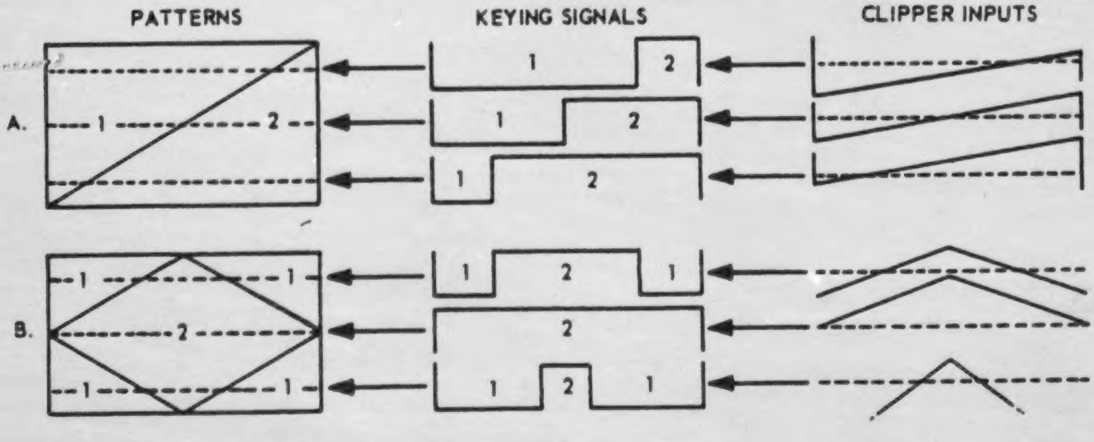

Figure 9. Special effects keying signals for horizontal lines shown in the patterns.

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illustration). To the right of the pattern are shown the keying signals that correspond to specific horizontal lines (scans). Each signal is marked to indicate the amount of time pictures 1 and 2 are displayed per line. Note the similarity of these signals, and their inputs, with the signals of the regenerative clipper just discussed (fig. 8).

3-9. To obtain a different type pattern, suppose we combine a 15,750-cps triangular waveform and a 60-cps triangular waveform to drive the regenerative clipper. This combination will cause the clipper input to rise to a maximum in the center of the field. Figure 9,B, illustrates the manner in which the clipper input changes to generate the keying signal that produces the diamond-shaped special effects pattern shown.

3-10. Sawtooth and triangular waveforms of line and field frequency are combined in many ways to obtain scores of special effects. If you understand the formation of the patterns in figure 9, you should be able to determine the keying signal and clipper input needed for other montage patterns.

3-11. Figure 10 shows the sections that make up a special effects generator. Inputs to the generator are horizontal and vertical drive signals. These inputs go through similar channels to develop sawtooth and triangular signals with blanking. Note the signals at TP1 and TP2 in the diagram; respectively identical-shaped signals appear at TP3 and TP4. However, the frequency of the signals appearing at TP3 and TP4 is 60 cps instead of 15,750 cps. Since the H-frequency channel and V-frequency channel are seen to have the same sections, we can treat both channels by discussing each section. Starting from the left in figure 10, notice that the drive inputs are amplified by the first section to attain the signal strength to drive the square-wave multivibrator and also the blanking multivibrator. The output from the square-wave multivibrator is fed into a triangular waveshaping network (active or passive type). This network effectively integrates the square wave to form the desired triangular signal. In the same section as the triangular generator, mixing is accomplished to insert the blanking pulse, thereby giving the output shown at TP1. The blanking pulse from the blanking multivibrator also provides an input to the sawtooth generator. This input is used to synchronize and form the output signal from the sawtooth generator section, shown at TP2.

3-12. The relays K1, K2, K3, and K4 are controlled from the special effects (S.E.) selector and mixer panel. K1 and K3 each determines which waveform is applied to the signal inverter section in its channel. The inverter simply makes it possible to obtain signals of opposite polarity, thereby increasing the number of special effects available. Relays K2 and K4 serve to select the signal of desired polarity for input-to-amplifier clipper sections. This section clips the blanking pulse to a prescribed amplitude, but does not alter the sawtooth or triangular waveshape.

3-13. The S.E. selector and mixer panel determines the input to the regenerative clipper section. The S.E. selector and mixer panel receives signals from the H-frequency channel, and the V-frequency channel. Selection of one or a combination of these two signals, along with the H-blanking signal, is accomplished by means of

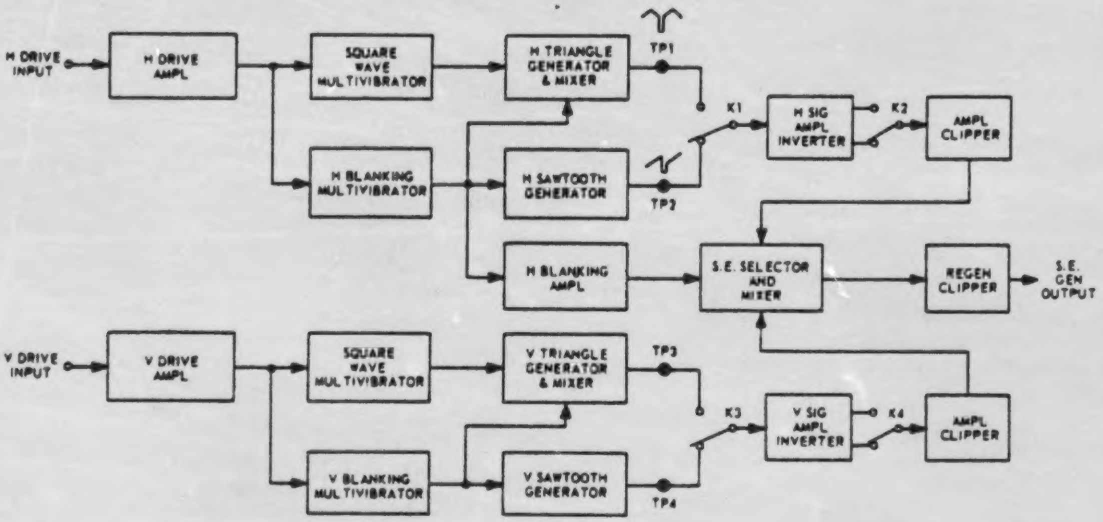
H DRIVE INPUT
H DRIVE AMPL
SQUARE WAVE MULTIVIBRATOR
H TRIANGLE GENERATOR & MIXER
TP1
K1
H SIG AMPL INVERTER
K2
AMPL CLIPPER
H BLANKING MULTIVIBRATOR
H SAWTOOTH GENERATOR
TP2
H BLANKING AMPL
S.E. SELECTOR AND MIXER
REGEN CLIPPER
S.E. GEN OUTPUT
V DRIVE INPUT
V DRIVE AMPL
SQUARE WAVE MULTIVIBRATOR
V TRIANGLE GENERATOR & MIXER
TP3
K3
V SIG AMPL INVERTER
K4
AMPL CLIPPER
V BLANKING MULTIVIBRATOR
V SAWTOOTH GENERATOR
TP4

Figure 10. Block diagram of a special effects generator.

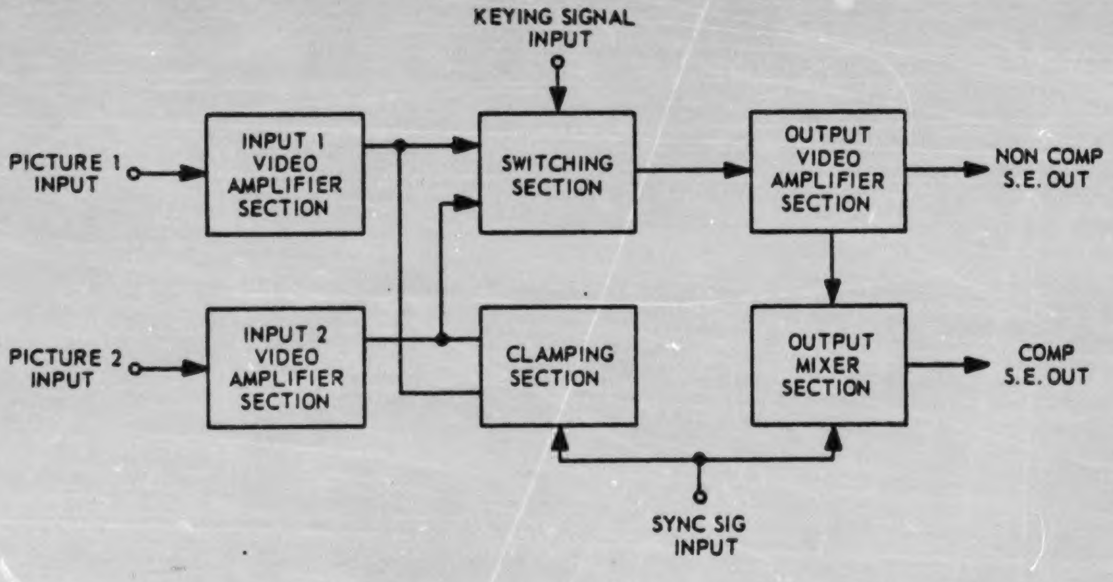

Figure 11. Block diagram of sections comprising a special effects amplifier.

relays which are energized with pushbutton switches. The pushbuttons are mounted on the S.E. selector mixer panel and are marked to show the special effects pattern associated with each switch. The pattern, as we explained earlier, is determined by the input to the regenerative clipper, which produces the keying signal. This signal is sent to the special effects amplifier.

3-14. **Special Effects Amplifier.** Figure 11 shows the sections that constitute a special effects amplifier. The picture inputs, 1 and 2, are amplified separately before being applied to the switching section and the clamping section. Note that the clamping section also obtains an input from the sync generator. This input is used to sample the picture inputs at different times during each horizontal blanking pulse. In this manner an average clamping potential is developed while picture channel isolation is maintained. The clamping section functions to keep the black levels of the two pictures equal to each other automatically. Thus, the picture signals to the switching section are properly clamped when they are fed into the switching section.

3-15. The two pictures are electronically keyed (gated) in the switching section to produce a montage display. This must be done without permitting the picture signals to interfere with each other. Figure 12 shows a network which effectively decouples one picture signal when the other is transmitted out. This decoupling is accomplished by means of two balanced bridge circuits—one comprisng Q3 and Q4, and the other comprising Q5 and Q6. Note that the circuits containing these transistors are identical. Diodes D1 and D2 are connected across one bridge circuit; there is no potential across them when the bridge circuit is balanced. Likewise, D3 and D4 have no potential across them when the other bridge circuit is balanced Adjustment of the potentiometers (marked "BAL" in fig. 12) and the bias applied to Q3 and Q6 will balance the bridge circuits. Assuming the adjustments are proper, let's now investigate how these bridge circuits operate in conjunction with the rest of the network to give an S.E. video output.

3-16. Picture 1 video is applied to the base of Q1. The collector of Q1 is connected in cascade to transistors Q3 and Q4. When no S.E. keying signal is present at the base of Q4, the bridge circuit is balanced and no signal is present across D1 and D2. Thus, the amplified picture 1 video at the collectors of Q3 and Q4 is not transmitted out between D1 and D2. Looking at the picture 2 side of the network, you see it is very similar to that of the picture 1 side. The only difference is the polarity of the diodes D3 and D4 with regard to the keying signal. This is an important fact, as we will explain shortly. However, when no keying signal is applied, D3 and D4 are across a balanced bridge. Because there is no signal developed across them, there can be no picture 2 video transmitted out between them; therefore, we see that neither a picture 1 nor picture 2 video signal is transmitted when the keying signal is absent.

3-17. We know that the keying signal is a series of rectangular pulses of varying pulse widths. To simplify, let's consider just one cycle of the keying signal and assume the high-level alternation equal to the low-level alternation (in other words, a square wave). Applying the high-level alternation to the bases of Q4 and Q5 drives these transistors to maximum conduction. Their collector voltages drop, thereby unbalancing the bridge circuits. Considering first the bridge circuit incorporating Q4, we find that the collector potential of Q3 is now higher than that of Q4. Diodes D1 and D2 therefore conduct and the picture 1 video signal is coupled to the S.E. video output line. Turning our attention to the bridge incorporating Q5, we have Q5 at a lower collector potential than Q6. Note, however, that diodes D3 and D4 are reverse-biased. This action determines that the picture 2 video signal will not be coupled to the S.E. video output line. The difference that we mentioned earlier concerning the polarity of the diodes is obviously quite important. The unbalance created during the high-level alternation of the keying signal caused D1 and D2 to conduct, but not D3 and D4. Picture 1 signal is transmitted; picture 2 signal is blocked. Such being the case for the high-level alteration, should not the opposite conditions occur when the keying signal switches to a low level? Using similar reasoning as before, we discover that D1 and D2 cut off, whereas D3 and D4 go to full conduction. Consequently, picture 2 signal is transmitted and picture 1 signal is blocked.

3-18. Depending upon the keying signal, picture 1 and picture 2 signals are coupled alternately through the switching section. If a difference in black level persists between the signals, it can be corrected with the balanced adjustment which changes the bias on Q1 and Q2. The S.E. video output is shown in figure 11 as going to the output video amplifier section. This section has two outputs—one that can be sent to a switcher in the camera chain, and one that is fed into the output mixer section where it is combined with the standard composite sync. The output from this section is therefore complete and can be distributed via distribution amplifiers to monitors for viewing.

4. Intercom

4-1. Any television installation that is operational will require some type of intercommunication facilities. The complexity of the intercom will be determined by the function which the TV facility serves. In some cases, there will be a need for simple telephone services; in other cases, requirements will necessitate the use of an amplifying system similar to a public address system.

4-2. **Facilities.** Installation of the television equipment may or may not have included intercom facilities. In some equipment, cable circuits will be available for intercom between camera, camera control, and control room facilities. Even when internal audio circuits are included, specific external audio equipment will not be supplied in conjunction with the video components. For example, a camera may have an intercom jack

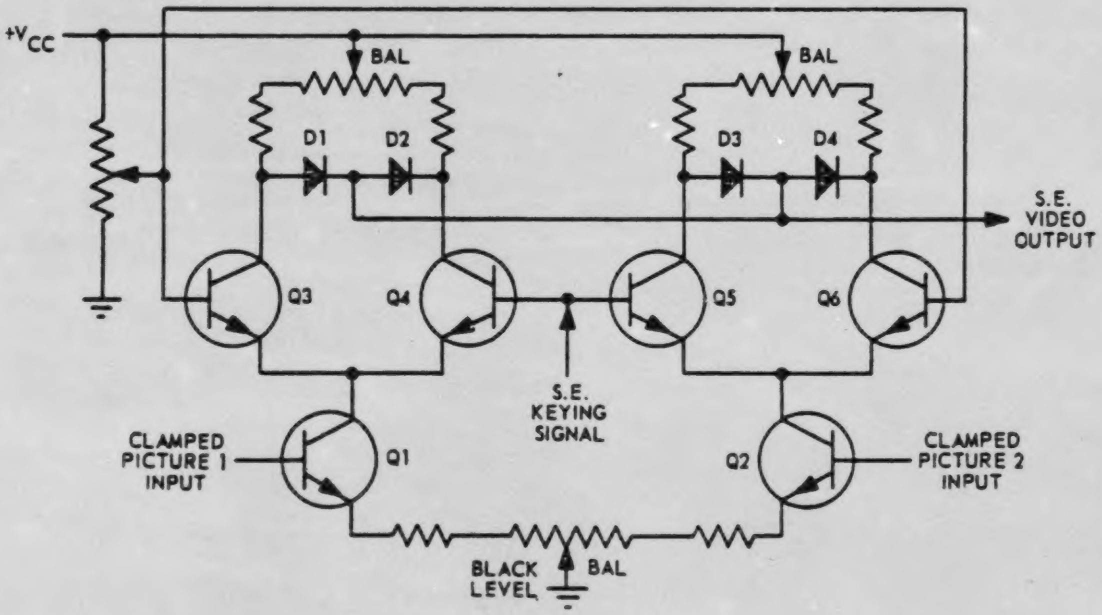

Figure 12. Transistorized switching section of a special effects amplifier.

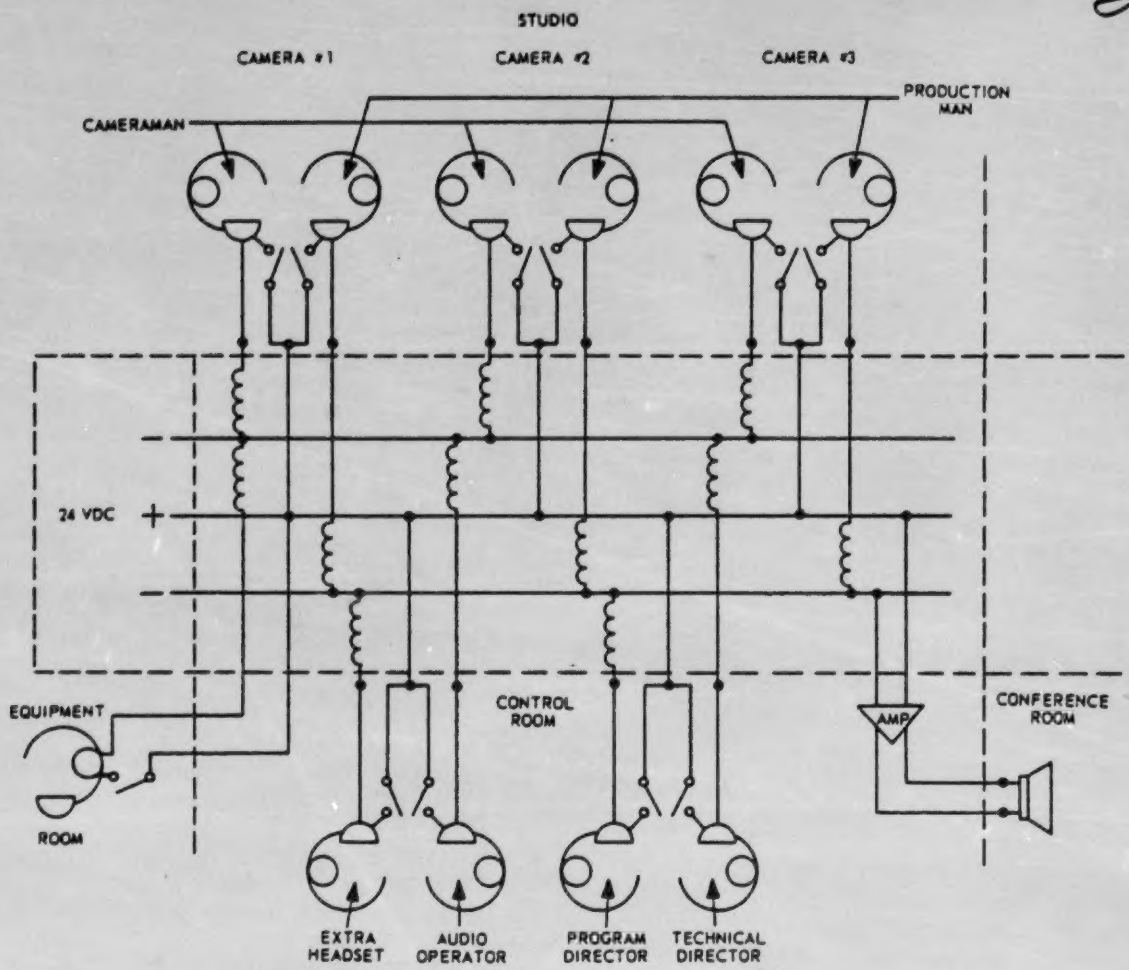

Figure 13. Layout of an intercom system.

but no headset is supplied. TV facilities require an intercom system for use in conjunction with program production or equipment maintenance.

4-3. **Representative System.** The representative system illustrated in figure 13 includes some of the features found in most systems. Layout variations in a given system will be discussed later. The illustration shows headsets (earpiece, microphone, and cord), terminal points, power supply, an amplifier, and a speaker. The illustrated arrangement permits communication between the control room personnel, camera personnel, production men on the floor of the studio, and equipment room operators. The added amplifier and speaker, used for conference room monitoring, permits one-way communication only.

4-4. The maintenance requirements for a system such as this will be governed mostly by its usage and the environmental conditions. The intercom system is normally trouble free; therefore, preventive maintenance will be the main requirement. This kind of maintenance consists of keeping plugs and terminal contacts clean, replacing broken moisture shield, and checking for loose screws inside the headsets and plugs. When you make visual checks, observe for broken wires, terminals, and plugs.

4-5. Although the intercom is normally trouble free, a few difficulties may occur. Occasionally, you will have a headset with a bent diaphragm or broken lead. If the headset is designed with a throwaway insert for the earpiece, the only repair required would be to replace the insert. If, however, in lieu of a throwaway insert, the earpiece is made up of separate elements, repair of the damaged elements is necessary. The microphone will probably be designed to use expendable inserts. These are normally carbon units with a moisture barrier as part of the assembly. Sometimes the carbon in a microphone unit becomes packed (as discussed in Volume 1, Chapter 6). You may be able to restore it to normal operation by a slight jar to loosen the carbon granules.

4-6. Some of the simplest checks of a faulty headset can be made with an ohmmeter. An ohmmeter intermittently connected across the headset terminals will cause a clicking sound if it is good. A carbon microphone can be checked by setting the ohmmeter to a scale that gives a midrange reading when connected. Then by talking into the microphone you will observe a slight meter movement if the microphone is good.

4-7. **System Variations.** There are considerable variations from system to system This is commonplace. However, most of the variations will be in the quantity rather than the types of equipment used. These will be such refinements as crossbar switching, which permits added circuits. If the distance is great, line amplifiers may be needed. Sometimes special circuits will require other types of microphones, speakers, and amplifiers. You may also find public address systems that have been modified for intercom use.

4-8. **Other Methods.** Up to this point we have been speaking of TV production applications of intercom systems. However, you should realize that some maintenance applications require methods other than those described. You, as a maintenance man, may find yourself in a situation where surveillance cameras are mounted on top of a building. If you are to adjust these cameras with the assistance of someone at the monitors, you and he will need to communicate. Since there will probably be no audio circuit available, you may need to use transceivers. Telephones may also be used as intercom for making maintenance adjustments. These two methods are cited to give you an idea of the variations you may encounter.

Audio and Video Equipment

IN THE TELEVISION field audio and video recording equipment are used extensively. There are two basic methods of recording: one is recording on magnetic tape and the other is recording on film. In this chapter we will discuss and compare the audio and video tape recorders. We will also discuss the construction and operation of a kinescope film recorder. Because of the necessity to convert film-recorded information to live video or video recording, we will discuss 16mm film projectors, slide projectors, and multiplexer units.

5. Recorders

5-1. Nearly everyone today is acquainted with magnetic tape recording in home entertainment and business dictating machine applications. All who are involved with TV maintenance should be aware of the use of magnetic tape in audio and video braodcasting. The magnetic recorder is a major unit, since it plays a very large part in the recording of TV programs. The magnetic tape recording techniques have progressed from the recording of lower audio frequencies to the recording of higher video signal frequencies.

5-2. We are also concerned in this section with magnetic tape recording of audio, and magnetic tape and film recording of television programs, including the construction, operation, and maintenance of both audio and video magnetic tape recorders. We compare their frequencies, control, tape transport, and electronic requirements. In addition this section treats kinescope film recorders, their operation, and their maintenance requirements.

5-3. **Audio Tape Recorders.** Perhaps you own a home tape recorder and have performed minor maintenance on it. In this section we are concerned with audio tape machines as they apply to TV production. You will notice that the terms "audio tape recorders" and "audio tape machines" are used interchangeably in this material. In the audio tape recording field there is a difference in the tape machine, tape recorder, tape deck, etc. The home variety tape recorder serves three functions: erasing, recording, and playing back audio frequencies. A tape recorder is usually limited to the erasing and recording of audio frequencies, and a tape playback machine is usually limited to the playback of audio frequencies. A tape machine can combine all three functions as in the home tape recorder.

5-4. For our discussion we have divided the audio tape machine into three main sections: transport mechanism, heads, and electronics. In the following discussion you will find variations in the functions of each of these main sections. For example, the tape heads are identified according to their functions of erasing, recording, or playback.

5-5. *Transport mechanism.* All of the tape machines require some type of mechanism to move the tape past the record and playback heads. Such mechanisms have been given various names, but *tape transport* seems to be generally accepted as standard. *Tape handlers* is the term used to designate machines designed for fast start-stop operation. These fast start-stop machines are usually a type of computer or laboratory tape transport which require the tape to start or stop instantaneously. In contrast, the standard machine requires about 1 second to reach full speed and perhaps 5 to 10 seconds to fully stabilize.

5-6. A good quality tape transport has the features of the mechanism illustrated in figure 14. These features include the tape supply reel, which is provided with either a friction brake or an active back-torque. The back-torque is supplied by the drive system or a torque motor. Back tension (torque) is necessary to keep the tape from becoming tangled due to the inertia of the tape reel. The tension idler holds a certain amount of tape in its loop; this spare amount of tape is temporarily let out during quick starts. A slight delay in time is allowed for the supply reel, which has appreciable inertia, to start turning at operating speed. The tension idler and back-torque work together to smooth out irregu-

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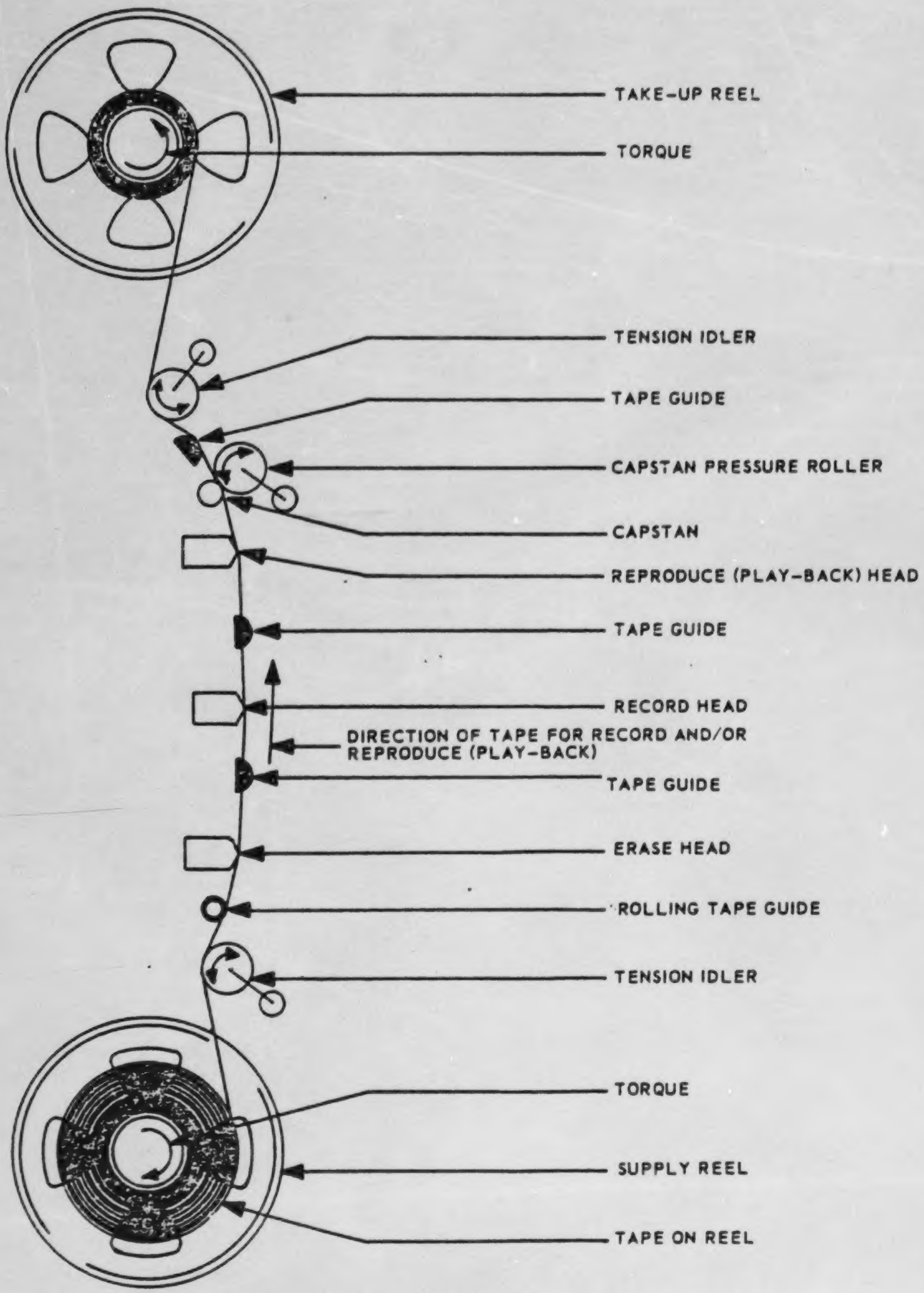
TAKE-UP REEL
TORQUE
TENSION IDLER
TAPE GUIDE
CAPSTAN PRESSURE ROLLER
CAPSTAN
REPRODUCE (PLAY-BACK) HEAD
TAPE GUIDE
RECORD HEAD
DIRECTION OF TAPE FOR RECORD AND/OR REPRODUCE (PLAY-BACK)
TAPE GUIDE
ERASE HEAD
ROLLING TAPE GUIDE
TENSION IDLER
TORQUE
SUPPLY REEL
TAPE ON REEL

Figure 14. Tape transport mechanism.

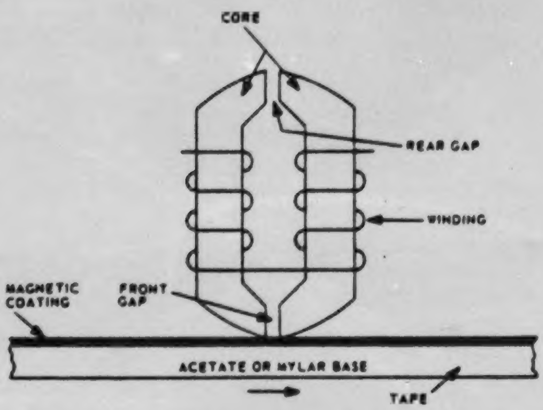

Figure 15. Construction of magnetic head.

larities caused by the rubbing of the tape against the supply reel sides, sticking together of tape layers, or other causes.

5-7. Again looking at figure 14, note that the tape is drawn from the tension idler, across the rolling tape guide, erase head, tape guide, record head, tape guide, and reproduce head. The force, which draws the tape across the heads at a constant speed, is provided by the capstan and the capstan pressure roller. The combination of the capstan, the tension idler, and the reverse torque of the supply reel keeps the tape under constant tension. There is friction between the tape and the stationary heads. This friction is a source of vibration. Attempts to eliminate this vibration are included in the design of the transport mechanism by using a rigid base on which to mount the transport components. Other causes of vibration are the amount of wrap around the head, smoothness of head faces, tape tension, tape condition, tape composition, temperature, and humidity. The capstan may be either the shaft of the drive motor or a shaft driven through a speed-reducing mechanism. The capstan and any associated mechanism must be made with precision or it will cause problems during both record and playback. This requirement for precision components includes the drive motor, as it must drive the capstan mechanism at a constant speed.

5-8. Immediately following the capstan and the capstan pressure roller is another tape guide. Each tape guide serves to keep the tape in alignment with the heads at all times. If the tape guides permit any vertical variation of the tape,

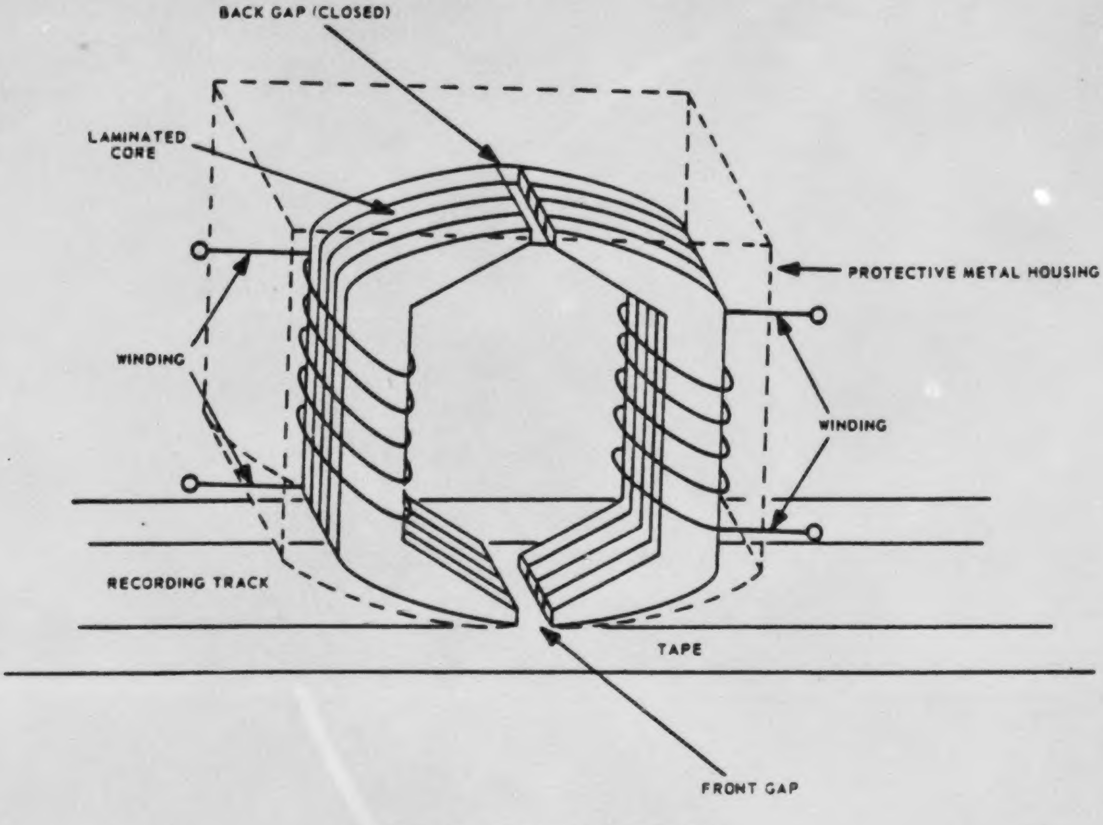

Figure 16. Laminated core tape head.

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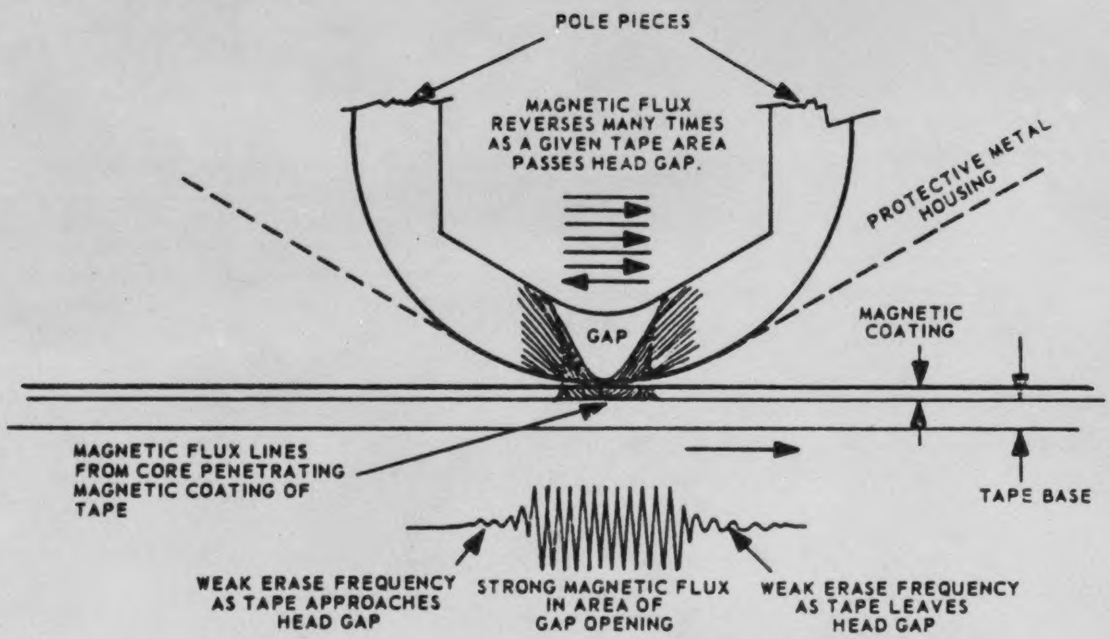
POLE PIECES
MAGNETIC FLUX REVERSES MANY TIMES AS A GIVEN TAPE AREA PASSES HEAD GAP.
PROTECTIVE METAL HOUSING
GAP
MAGNETIC COATING
MAGNETIC FLUX LINES FROM CORE PENETRATING MAGNETIC COATING OF TAPE
TAPE BASE
WEAK ERASE FREQUENCY AS TAPE APPROACHES HEAD GAP
STRONG MAGNETIC FLUX IN AREA OF GAP OPENING
WEAK ERASE FREQUENCY AS TAPE LEAVES HEAD GAP

Figure 17. Action of high-frequency erase head.

a possibility exists of attenuation of the recorded signal during reproduction. In extreme cases the signal could be lost entirely, or the erase head would either fail to erase or improperly erase when a recording is made. The tension idler near the takeup reel serves the same purpose as the other tension idler. The torque on the takeup reel changes according to the amount of tape on the reel.

5-9. *Heads.* Three tape heads may be used on the more expensive tape machines. Some machines, such as those designed for home use, use the same head for record and reproduce. It is possible to use the same head for erasing the tape; however, if the same head is used for erasing as well as recording and reproducing, it will require an additional runthrough of the tape.

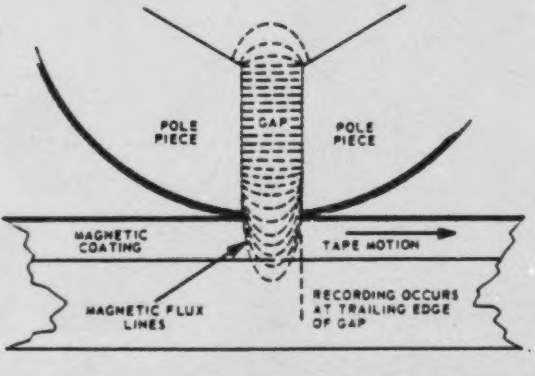
POLE PIECE
GAP
POLE PIECE
MAGNETIC COATING
TAPE MOTION
MAGNETIC FLUX LINES
RECORDING OCCURS AT TRAILING EDGE OF GAP

Figure 18. Flux lines in a recording gap.

5-10. Although one tape head can be used for the three purposes of erasing, recording, and reproducing, there are some differences in construction of the heads. (The head differences will be discussed later.) The basic construction of tape heads is the same—that is, the head consists of a core of permeable material which is wound with a coil of wire (as shown in fig. 15). This core of permeable material is formed into a modified circular shape, with a gap at the point of tape contact. The core material is usually of a laminated construction (as illustrated in fig. 16) rather than nonlaminated. The nonlaminated heads are cheaper to construct, but they usually produce poorer results. The laminations, by reducing magnetic losses due to eddy currents; produce a better response to higher frequencies.

5-11. The core of the head is wound with a number of turns of wire, but the number of turns will depend on the purpose for which the head is designed. The manner in which the core is wound will be dictated by the head use; also, two windings may be used. Most of the newer heads follow the two-winding design, one winding on each side of the gap. In most of the newer designs the two windings will be terminated externally, thus they may be connected in a parallel or series arrangement as desired. The core and winding is inclosed in a protective metal housing to prevent the winding from picking up hum emanating from motors, transformers, etc.

5-12. So far all the heads under discussion have been of the electromagnetic type. To further expand on the erase head, some are constructed to use either a single permanent magnet or a series of permanent magnets to set up a magnetic field. If a single magnet is used, the tape will be erased by the magnetic flux. However, with more than one magnet, the tape will be erased by the changing cycles of the magnetic flux fields.

5-13. The more popular erase heads are those which use a high-frequency current to create an a-c magnetic flux. This current is supplied by the bias oscillator, which also provides the bias current to the record head. The magnetic flux lines penetrate the magnetic coating of the tape, as illustrated in figure 17. The a-c erase head has fewer turns of wire than the standard playback head, and it passes current easier and operates better at the higher frequencies. Another feature of an a-c erase head is a wider gap which permits the tape particles to change direction more times, thus giving a more complete erasure of the tape. You will notice that as the tape approaches and then leaves the gap in the head, the erase action builds up from zero to maximum and back to zero. Thus, any magnetic pattern which was previously recorded is obliterated by the action of the high-frequency bias oscillator.

5-14. When an alternating current is sent through the winding of a record head, a magnetic field corresponding to the applied current is produced in the core (see fig. 18). The magnetic field has a great deal of difficulty passing through the nonmagnetic gap in the core. However, when the magnetic coating of the tape closes the gap, the field can easily complete its journey via the tape. The tape now becomes magnetized in accordance with the fluctuations of applied current.

5-15. The magnetic fluctuation of the tape continues until the instant the tape passes the trailing edge of the gap. The magnetic orientation at the instant of departure from the gap edge is the pattern that remains on the tape. For the best possible recording, the trailing edge of the gap should be as straight and sharp as possible. A principle difference between heads of poor quality and high quality is the definition of the gap edge. The amount of electrical signal required to produce a certain amount of magnetic flux on one head may create a stronger magnetic flux on another head because of differences in efficiency or elements of design. The signal level that causes distortion varies among heads of different manufacturers. You must take these factors into account if you substitute a different make or model of head for the one that originally came with the tape recorder.

5-16. As the signal current is fed to the record head, the high-frequency bias current is supplied simultaneously to this head, as shown in figure 19. The residual magnetization of the tape is accomplished by passing the signal current, plus a high-frequency bias current, through the recording head windings. This technique is referred to as direct recording.

5-17. The high frequency of the bias oscillator serves to activate the head over the linear portion of its magnetization curve. This linear operation puts the audio signal in a magnetization area for the most faithful recording. If, however, the bias signal is increased until the head is saturated, the linear operation will be disturbed. The final magnetization produced in the tape is determined by the last flux encountered close to the trailing edge of the gap as the tape leaves the gap area. For this reason the length of the recording gap is not as critical, within limits, for recording heads as it is for reproducing heads. The recording heads usually will have a gap in the range of 0.0005 to as much as 0.001.

5-18. Certain features of the playback (reproduce) head are required to provide full response to the audio frequencies. One requirement is that the head gap be very narrow, that is, 0.0001 inch or smaller. A large number of turns of wire is required in the winding since the head must be sensitive to the changes in flux recorded on the tape. The playback head functions in an opposite manner to the record head; that is, the tape induces a flux into the head core. The flux passing through the core induces a voltage into the winding, causing current flow in the associated circuit. This signal current is amplified by the playback amplifier for operation of speakers, headphones, or other devices.

5-19. The playback head is of prime importance in the faithful reproduction of a recorded signal. For example, if we assume that a head is good mechanically and it is playing back a signal which has all frequencies recorded with equal magnitude, we will find that the higher audio frequencies will produce a greater voltage output. An inherent characteristic of a playback head is that the rise in output is proportional to the rise in frequency. This is true up to a point which is determined by the characteristics of the head and head gap. The ability of the playback head to reproduce high frequencies varies inversely with the width of the gap. This means that a narrow gap is necessary for good high-frequency response. However, remember that although a new head may have a narrow gap, as the head wears the gap will become wider, and as a result, the high-frequency response will drop off. Also, along with gap width, the definition of the edge

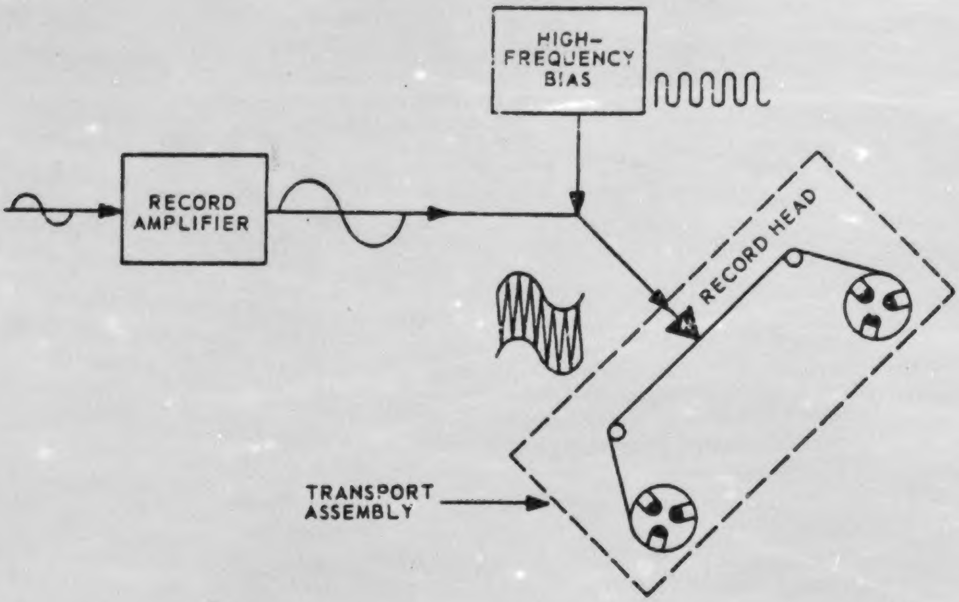

Figure 19. Recording with high-frequency bias.

of the head must be smooth to produce high frequencies. If the edges of the gap are not straight and sharp, the gap behaves magnetically as though it were much wider than its physical dimensions.

5-20. Other factors which affect the frequency response of the head are tape speed, smoothness of the tape, pressure of the tape against the head, and quality of the tape. The tape speed is important because the more rapidly the changes in flux are drawn across the head gap, the stronger the voltage induced into the head windings. This added strength, in turn, gives improved frequency response to the recorded signal. You can understand this condition if you consider that a slow moving tape will cause the head to see an average change in the flux and not each small change, which is necessary to reproduce high frequencies. Smoothness of the tape and tape-to-head contact are directly related in their effect on frequency response as well as voltage output. If the tape is rough, the magnetic particles are not maintained constantly close to the head, which is necessary to induce a smooth flow of flux variations. The rough spots or portions of the tape will move the particles farther from the head and cause weakening of the flux changes; thus, the high frequencies will be lost. Carrying this thought further, you can understand that the same losses will be prevalent if the pressure holding the tape against the head is weak.

5-21. *Electronics.* Typical electronic circuits used in tape recording are indicated by figure 20. There will be certain refinements as dictated by performance requirements. Normally the higher the frequency response required the better the overall quality of the circuit components will be. Even though the record head requires very little drive power, the need for bias injection, impendance matching, and possibly preemphasis makes it important to use the correctly designed amplifiers in the recorder. In the playback circuits typical audio amplifier circuits are used. In some recorders there is dual utilization of circuits for record and playback. In recorders there is a requirement for voltage equalization of frequencies in the output. Earlier a statement was made that the higher the frequency the more the voltage output; for the lower frequencies the opposite is true. Therefore, the very weak low frequencies must be boosted. It is not enough to increase the gain of the amplifiers. The problem is to boost the low frequencies and limit the high frequencies. In most instances, it is sufficient to add RC networks to the input signal path of an amplifier. To attenuate the high frequencies, RC network values are selected that will result in bypassing a major portion of voltage of the higher frequencies to ground. The reduction of the higher frequencies' input voltage of an amplifier results in a relative boost of the lower frequency voltage. Frequency-selective feedback circuits between amplifier stages may also be used to equalize the output voltages of the high and low frequencies.

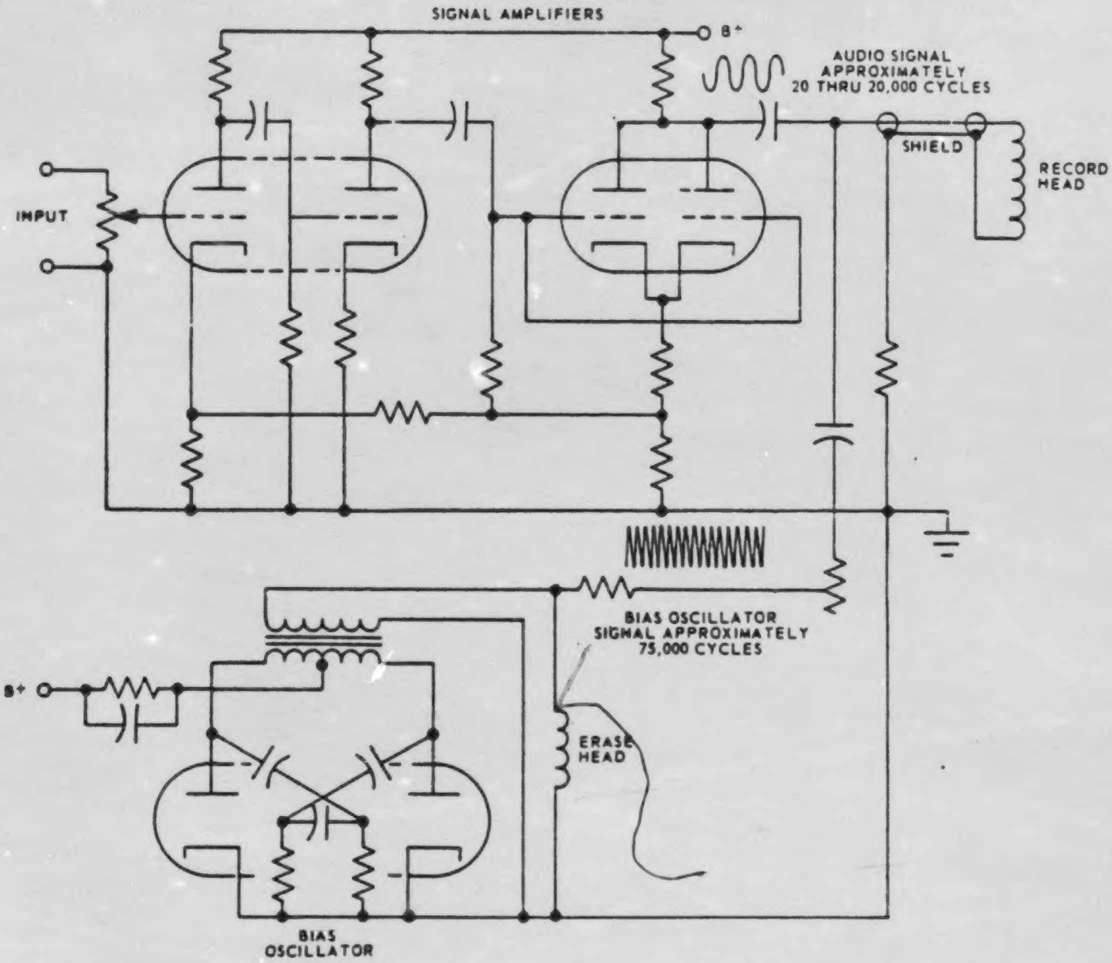

Figure 20. Typical record and bias oscillator circuits.

Many variations of equalization circuits are used in both playback and record amplifiers.

5-22. *Trouble diagnosis.* To diagnose troubles in a tape machine, you need to remember that a combination of features can cause trouble. In a tape machine you have a group of mechanical functions as well as the various electrical circuits. Indications obtained from the electrical circuits will point to most of the troubles. These troubles may or may not be in the mechanical mechanism, but you will have to "read through" the troubles to make your diagnosis. Once you detect a malfunction you should look immediately for the cause; however, a quick mental reference to the most common troubles and their causes should speed your diagnosis.

5-23. The word "wow" is used to describe a slow variation of speed, whereas "flutter" describes a fast variation of speed. If the speed is consistently wrong, the audio signal will be off pitch. This condition is easily recognized with music but can be difficult to determine with spoken words. A "wow" could be caused by certain faults, such as a slipping belt, lack of proper pressure on capstan, motor winding damage, or uneven tape surface. A "flutter," which will be much faster, would more likely be caused by something moving at a higher speed. The capstan could be out of round and give this fault with every revolution. Sometimes a tape guide can cause a bouncing action to be repeated at a fast rate. A signal which is consistently off pitch or key may be caused by insufficient or excessive drag on the tape as it passes through the transport system. This could be incorrect action of the supply reel, the pressure pads, tape guides, or improper threading of the machine.

5-24. If you have an indication that the output seems to be weak, or that it is not giving full response to the higher frequencies, you might look

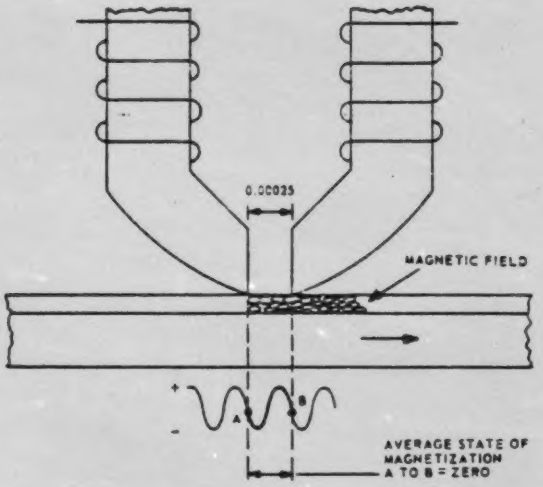

Figure 21. Gap effect at high frequencies.

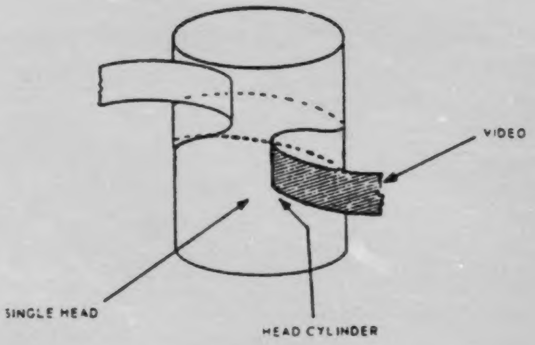

Figure 23. Full-helical recorder head.

for an electrical trouble. Pause for a moment and think what would happen if you have only a portion of a track passing over a head. We know that the strength of the output signal is relative to the magnetic flux recorded on the tape and the tape speed. You already know that head wear will cause a drop in high-frequency response, but if the track or head is misaligned, you will not get full benefit from the recorded signal. You may need to check head wear, track, and head alignment. If these seem to be correct, then check the circuit components. Again, you can solve many of the tape machine problems by "reading" the symptoms and making a logical conclusion.

5-25. For still another example of a problem, let us assume that when you make a recording and play it back you don't get a signal. There are two ways to start checking. Use a known good machine to check the tape or a known good tape to check the machine. If you determine that the trouble is in the record or playback portion, you should proceed to check out the items in those sections. If the trouble is in the record circuits, you may check the input source or the bias oscillator; either one could cause a failure in the record mode. If the bias oscillator is not working and the machine uses this same signal to erase the tape, a recorded tape would not be erased prior to a new recording. This is one quick check of the bias oscillator. A substitute microphone can be used to make a quick check of the input source. Many recorders have a monitor jack which can be used to determine whether a signal is being fed into the recorder. Most recorders have a record indicator, either a light or a meter, which gives a visual indication of the input. By checking the circuit of the recorder in use, you will be able, through a process of elimination, to narrow the area of trouble to a limited number of stages. From this point it will be necessary to make the more routine checks of tubes and other components. To prevent head magnetization, do *not* check the continuity of heads with an ohmmeter.

5-26. A trouble in the playback circuits is most readily found by using a known good tape for playback. With some machines you have an

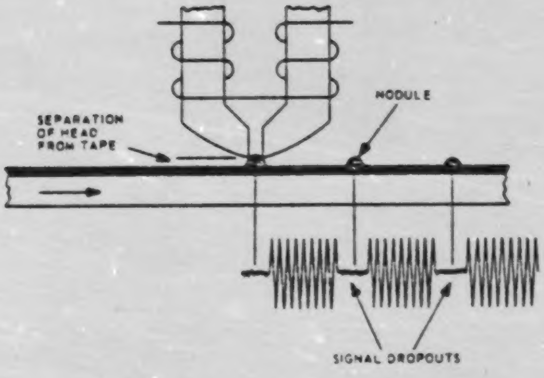

Figure 22. Effect of surface defects.

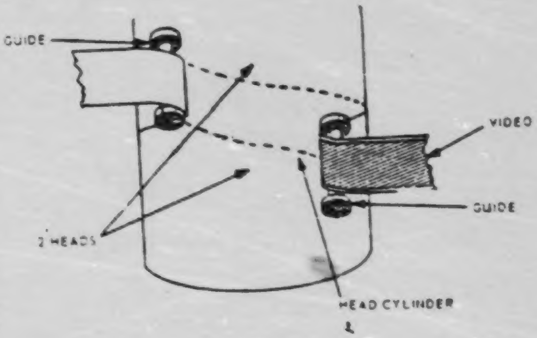

Figure 24. Half-helical recorder head.

intermediate output which can be checked to determine if the signal is reaching a given point in the machine. Some machines have a visual output indicator; if you have this type, you will know that all circuits are good up to a point. Sometimes a headset output will be provided in a stage prior to the power output; here, all but the last stage could be eliminated as the source of trouble. In all cases it is a matter of taking logical steps toward localizing the trouble to an area, to a circuit, and finally to a component or components.

5-27. **Video Tape Recorders.** The video signal frequency range for television tape extends from very low frequencies (approaching d-c) to the upper limit of 4 MHz. As previously indicated, the size of the head gap becomes very important in the magnetic recording of higher frequencies. For a given gap size and tape speed, there is a frequency above which recording is impossible. This condition occurs when the recorded wavelength of the signal frequency just equals the width of the head gap. In figure 21, note that the positive and negative portions of the cycle appear across the gap simultaneously and cancel each other. Maximum output is obtained when the recorded wavelength is twice the width of the head gap.

5-28. The relationship between recorded wavelength, frequency, and velocity of the tape is expressed by the formula:

$$\lambda = \frac{V}{F}$$

where λ = recorded wavelength (in), V = tape speed (in/s), and F = frequency (Hz) of the signal. From this formula it may be determined that as the velocity of the tape increases the recorded wavelength also increases.

5-29. The original approach to recording the higher video frequencies was simply to increase the speed of the tape so that the wavelength became a usable size. Video recorders that use extremely narrow gap heads and very rapid moving tape are called longitudinal recorders. Longitudinal video recorders have many drawbacks. Primarily, the picture quality (resolution) is poor, because the active read/write speed is limited by the tape-handling capabilities of the transport including problems of spooling the tape and avoiding tape overthrow. Also, an excessive amount of tape is required.

5-30. Another approach to the recording of the higher video frequencies consists of pulling the tape at a practical speed past a rotating head, resulting in an increase of head-to-tape velocity. Systems that use the rotating head principle also apply other techniques to improve the recording of video signals. One of these techniques is to use frequency modulation (FM) for recording the signal information. The FM technique solves the problem of bandwidth. The largest frequency span that can be accommodated by direct recording is 10 octaves (15 Hz–15K Hz). Since the video signal has a span greater than 18 octaves (0–4MHz), direct recording is not practical. This difficulty is overcome by using a frequency modulator to change the video information into an FM signal, with a full lower sideband and a vestigial upper sideband. In one application the video signal is frequency modulated onto a carrier from 1 to 7 MHz wide, a span of only 3 octaves. The reduction in the span of frequencies is important in the designing of the inductors used in the record/playback heads. The use of FM permits the recording of the signal at a constant amplitude.

5-31. The constant level FM can be amplified and limited in playback to reduce the effect of signal dropout. Signal dropout is due primarily to tape surface defects. These tape surface defects result in poor contact between the head and tape, resulting in substantial loss of signal (see fig. 22). Another technique is to allow the head to penetrate or intimately contact the tape.

5-32. Video tape systems that use the rotating head principle will vary in methods used to scan the tape physically. The traverse and helical (either full-helical or half-helical) are the principal scanning methods used.

5-33. The helical method of recording video signals utilizes 1-inch or 2-inch tape wrapped diagonally around a hollow cylinder. Inside the cylinder there is a rotating head assembly containing one or two heads. Through a cutaway in the cylinder, the rotating head assembly is permitted to make contact with the moving tape. A single rotating head is used in the full-helical method and the tape is wrapped around the cylinder (see fig. 23). The head scans one or two fields, then leaves the tape during or near a vertical blanking period. Two heads are used on the rotating assembly in the half-helical method and the tape is wrapped over halfway around the cylinder (see fig. 24). Each head records or plays back one field with sufficient overlap to allow for electronic switching from head to head during vertical blanking. In either method (see fig. 25), the recorded video tracks are laid down at a slight angle to the edge of the tape. Audio and control timing signals are recorded in longitudinal tracks along the top and bottom edges.

5-34. Mechanical assemblies of helical recorders include the scan heads, a transport system with takeup and supply reels, tape guides,

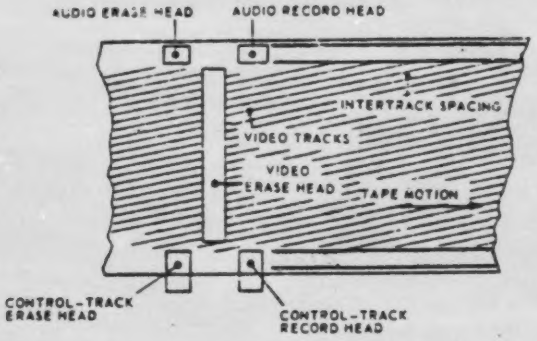

Figure 25. Track pattern laid down by a helical recorder.

and a tape tension control system. Signal circuitry includes the FM modulator, record and playback amplifiers, sequence switchers, FM demodulator, and video amplifiers. Servosystems are used to control the tension of the tape and speed of the head assembly and the capstan. Except for the scanning method, basic operating principles are essentially the same for the helical and traverse video recorders.

5-35. The traverse scan video recording system uses a rotating head assembly to lay down video tracks transversely (across) a 2-inch-wide magnetic tape. The rotating head assembly contains four small heads located at 90° intervals around the circumference (as shown in fig. 26). The video signal is fed to the individual heads via a slipring and brush assembly.

5-36. The tape is pulled past the head assembly at a velocity of 15 inches per second and the assembly rotates at 240 rps. A head assembly with a tip-to-tip diameter of 2.07 inches has a circumference of 6.5 inches. Since the head revolves at 240 rps, the head-to-tape velocity or read/write speed of the 2.07-inch diameter head is 1560 inches per second. As illustrated in figure 27, the tape is held concentric to the rotating heads by a special tape guide.

5-37. This special guide provides for tape stretch as the head penetrates the tape (negative clearance). Figure 28 illustrates this action. Since the position of the guide in relationship to the heads is adjustable, the amount of tape penetration may be controlled. The height of the guide may also be adjusted.

5-38. Refer to figure 29 for the location of the tracks on television tape. As one head of the assembly starts across the tape, the tape will move a small amount before the head completes its arc across the tape. These motions result in the signal track being recorded with an angle slightly less than 90°. The rotating head contacts the tape for an arc of approximately 120° and records a track 10 mils wide. A 5-mil guard band is provided between each track to prevent crosstalk. A 70-mil track across the top is erased to provide for longitudinally recording audio information. A 240-cps control signal is recorded on a separate track along the bottom of the tape. A cue track is recorded parallel to the control track.

5-39. The head assembly rotation of 240 rps is four times the TV field frequency of 60 cps. Thus, one rotation of the head assembly lays down four tracks which are equal to one-fourth of a field (about 65 lines) and one track is about 16 lines. In the 120° arc of a head contact, the video signal information is recorded in a 102° portion of the arc. Since the heads are 90° apart, two heads are simultaneously in contact with the video recording area during a 12° overlap. The 12° overlap insures that a smooth

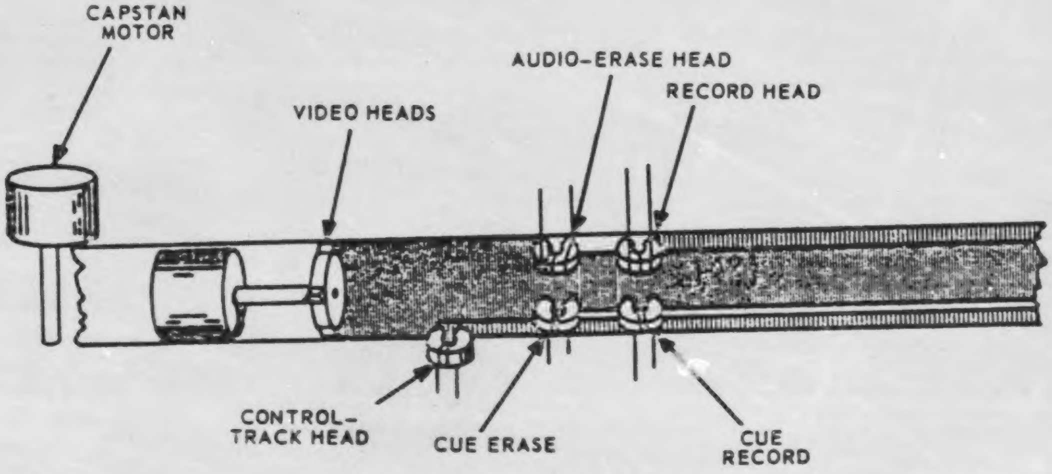

Figure 26. Traverse recorder head.

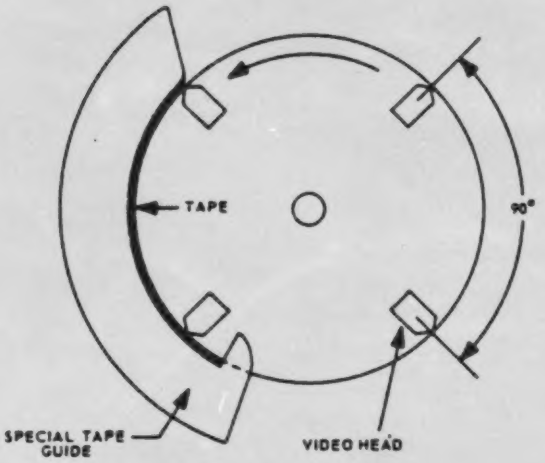

Figure 27. Rotating head assembly.

continuous signal will be reassembled. During playback the overlap is eliminated by an electronic switching process that disconnects the head nearing the end of a track, then connects the head that is beginning the next track. The switching is done during horizontal retrace.

5-40. Errors in timing may occur between record and playback. For example, in the playback position, a head may enter or leave a track earlier or later than it was recorded. These errors in time will appear during playback as horizontal displacements of vertical lines in the picture and are known as time-space errors or space distortion. One factor that contributes to space distortion is incorrect alignment of the position of the tape in relationship to the rotating head assembly. The adjustable special tape guide determines the position of the tape in relationship to the head assembly. Provisions for adjustment of the tape guide include the initial (preset) mechanical adjustments plus automatic adjustments during operation by a servosystem. A type of space distortion known as quadrature errors results from slight deviations in the spacing on the rotating assembly of two adjacent heads from a true 90°. To correct quadrature errors, some systems provide for mechanical adjustment of individual head angle, plus adjustable electronic delay circuits. Servosystems are used to reduce the effect of other timeing errors that cause picture distortion, flutter, and loss of snychronization. Closed-loop servosystems control the motors that drive the rotating head assembly.

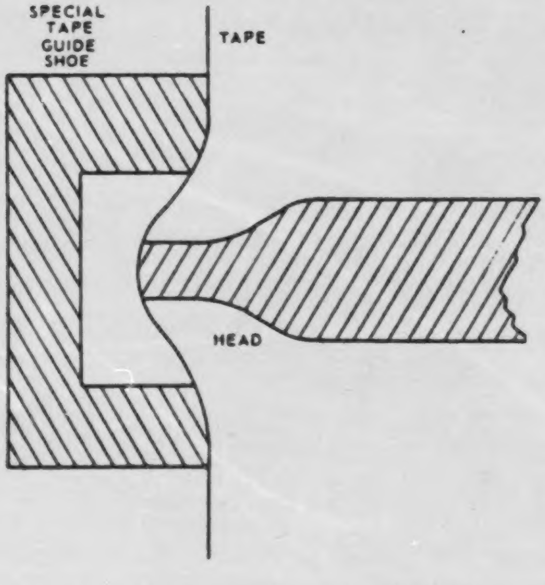

Figure 28. Tape penetration by video head.

5-41. Like the audio tape transport, the video tape transport must have a highly stable mounting surface. The rigid mounting is even more important for a video transport because the tape must be held under greater tension and be able to withstand higher speed stops on wind or rewind. These stops are accomplished by a fail-safe braking system. (The arrangement of the components of a tape transport is shown in fig. 30.) It is important that the tape speed be accurately controlled over the heads. This is done in the record mode by using a constant speed motor to drive the capstan, which controls the rate at which tape is drawn over the heads. When the tape is played back the recorded speed is accurately duplicated by servocontrol of the reproducer capstan speed, insuring that the reproduce heads track constantly over the recorded tracks. The capstan servo input signal is obtained by comparing a recorded signal on a control track with timing pulses from the rotating head assembly.

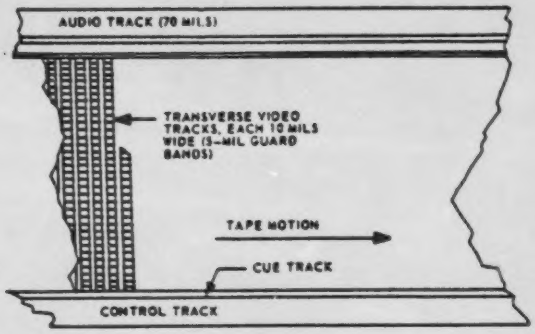
AUDIO TRACK (70 MILS)
TRANSVERSE VIDEO TRACKS, EACH 10 MILS WIDE (5-MIL GUARD BANDS)
TAPE MOTION
CUE TRACK
CONTROL TRACK

Figure 29. Traverse tracks on television tape.

5-42. To prevent mishandling of the tape, or tape damage, the supply and takeup reel as-

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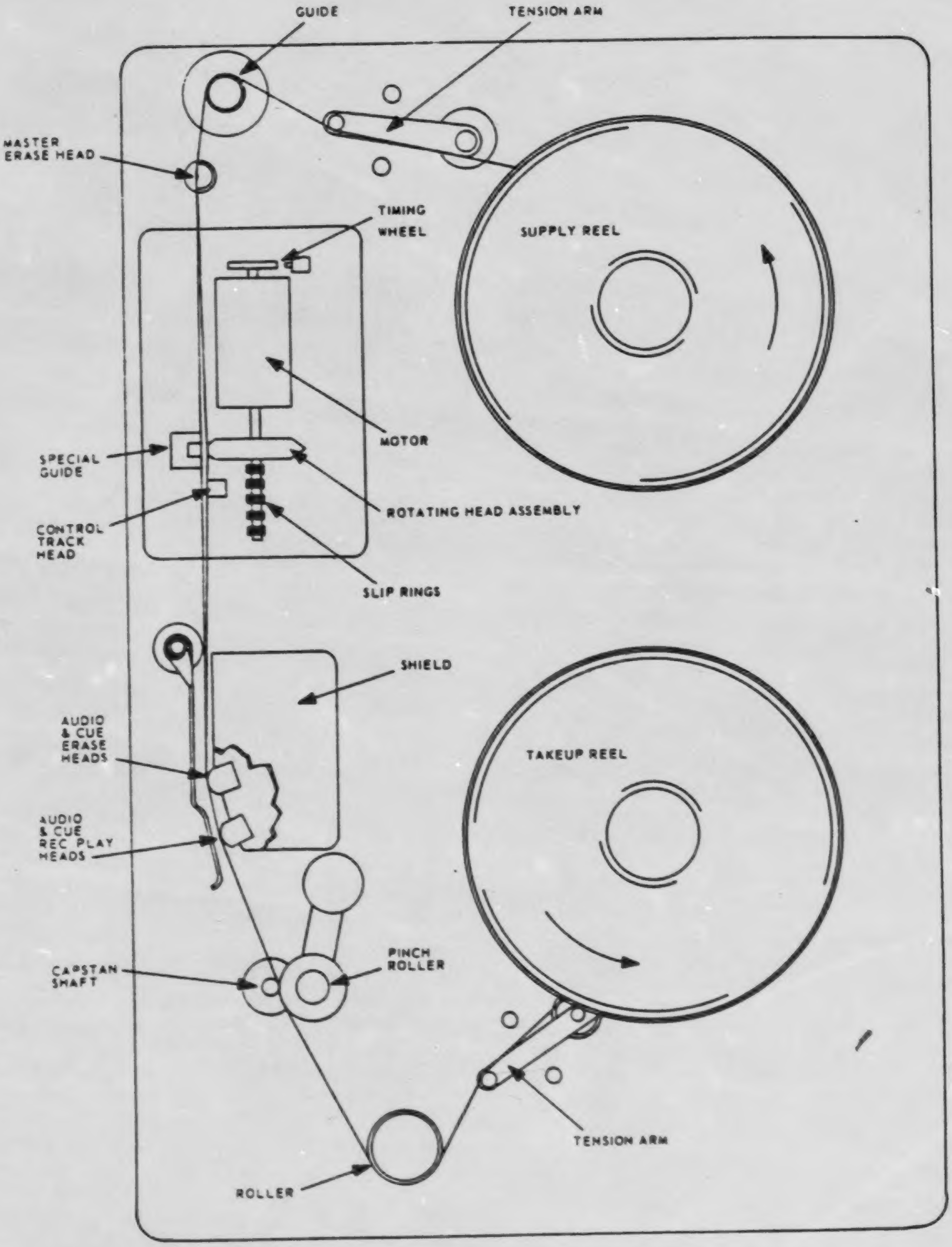

GUIDE
TENSION ARM
MASTER ERASE HEAD
TIMING WHEEL
SUPPLY REEL
MOTOR
SPECIAL GUIDE
ROTATING HEAD ASSEMBLY
CONTROL TRACK HEAD
SLIP RINGS
SHIELD
AUDIO & CUE ERASE HEADS
TAKEUP REEL
AUDIO & CUE REC PLAY HEADS
CAPSTAN SHAFT
PINCH ROLLER
TENSION ARM
ROLLER

Figure 30. Tape transport.

semblies are each driven by a separate electric motor through a hysteresis clutch. The current flow through the clutch is normally proportional to the amount of tape remaining on the tape reel fitted to the assembly's turntable. A fixed maximum current, however, is driven through the supply reel clutch coil in the rewind mode and through the takeup reel clutch in the fast forward mode. This provides for rapid completion of either of these two modes. Tape tension between reels is maintained by arrangement of the drive motors in such fashion that they tend to drive the tape reels in opposite directions, with each reel driven to take up tape. When all slack tape has been taken up and the slack takeup idlers are under tension, the tape will be held at rest, ready to be drawn over the heads by the action of the capstan assembly. Additional control of tape tension against short-term or transient disturbances is provided by two slack takeup idlers which also serve as tape guides. One idler is fitted at the exit from the tape supply reel assembly, while the other is fitted at the entrance to the tape takeup reel assembly.

5-43. The audio and cue record/reproduce heads and audio and cue erase heads are all accommodated in one head assembly which follows the rotating head assembly in the tape path. These heads function in a conventional, longitudinal fashion. The head assembly is mounted on a precision-machined base plate.

5-44. The electronic circuits of the video tape recorder can be grouped into two main groups, those used to control the operation of the tape recorder/reproducer and those used to amplify or otherwise process the signal(s). Usually the tape machine will incorporate, as subassemblies, all the basic units necessary for producing a compatible video signal and the audio. These units may include sync generators, power supplies, and distribution amplifiers, plus the possible inclusion of such things as built-in test equipment, and complete monitoring facilities. In other words, the video tape machine electronics may include everything necessary for a CCTV system with the exception of the camera.

5-45. As already indicated, the rotating heads and the precision movement of the tape require a great deal of control. Therefore, much of the electronic circuitry will have to do with servosystems. The video signal circuits will differ from audio circuits (discussed previously) in frequency range and bandpass of circuits. Since the video signal has a range from near d-c to approximately 4 MHz, it is necessary to apply this signal to a variable oscillator to obtain an FM frequency. This frequency may then be applied to another mixer circuit or directly to amplifiers and drivers to give us a constant amplitude FM signal for driving the video recording heads. For playback the signal is amplified and limited to a constant level, then fed to a demodulator to drive the video circuits. The actual frequencies used and the manner in which various conversions are made vary with manufacturer's design. To study details of circuits and frequencies, you will need to read the manuals concerning the particular make and model of the tape machine you are using.

5-46. Some of the video tape machines have various lever controls in addition to pushbutton controls. Newer models are entirely pushbutton operated, with provisions for remote operation during the playback mode. In the record mode there would be few instances where the machine would be operated remote. Some exceptions would be when copying tapes or using the machine as a training aid, in which case the tape would be played back once before erasure and reuse. One important point is that the machine usually is designed so that you cannot start it in the record mode without manually releasing the lock on the lever or pushbutton used to turn the machine on.

5-47. The actual number of other controls depends on the make and model of the video tape machine you are using. These include the controls that adjust the levels, alignments, equalizers, deflection circuits, and others. Other mechanical controls may be located at points throughout the tape machine. At those times when the electronic controls will not make sufficient corrections, it is necessary to make mechanical changes. An example is the head-tip penetration which can cause the signal to drop out when there is not enough negative clearance. If you have a weak signal on playback, and adjustment of various level controls does not result in a satisfactory signal, you should check the mechanical contact between the head and the tape. If the special tape guide is adjusted incorrectly or the head tip is worn until the tape is not stretched properly, you will have the same weak signal symptom.

5-48. Much of the maintenance of a video tape machine consists of cleaning, lubricating, replacing tubes (tube models only), and evaluating overall performance. There should be a schedule, such as the one recommended by the manufacturer, for oiling and cleaning. Local conditions will affect the cleaning routine for filters; for example, an installation in a relatively dust-free area will not require filter cleaning as often as a portable field unit. Do not overlubricate, but be sure to apply enough oil. Tube replacement usually will not be a problem, except to keep balanced drivers and amplifiers in circuits having multisignal paths. In transistorized tape machines, special effort is made to work out initial troubles at the time of installation; consequently, they are trouble free in comparison with tube-type machines.

5-49. Whether designed for audio or video operation, magnetic tape is a flexible plastic base material. The coating may be one of a variety of magnetic materials which cannot tolerate rough handling. Rough handling may erase, partially or completely, a recorded tape. The quality of the signal obtained from a tape depends upon the smoothness of the coating and the closeness of tape-to-head gap contact. Any physical damage to the recording surface then results in mechanical distortion, thereby degrading the signal. Other considerations of tape care include the smoothness of each surface over which the tape travels through the tape transport mechanism. Excessive temperatures during operation or storage can cause damage to the mechanism, and tape guides can cause edge damage. A change in humidity or excessive dampness is another factor, and you must also watch for any sign of buckling, cinching, or slippage on the reels.

5-50. Troubles in video tape recorders/reproducers can be diagnosed in the same basic ways as in other equipment. You take any given symptom, check the obvious trouble sources first, then the less likely, and on to the least likely. Use available publications and follow the recommendations of the manufacturer whenever possible; this practice may lead you to a quick solution.

5-51. **Kinescope Recorders.** The recording of television programs on motion picture film is called kinescope recording. It is a means of storing, on motion picture film, electrical waves corresponding to both the picture and the sound portion of a television program. Kinescope recording equipment may be used to record a transient display where immediate observation by television is a necessary but not sufficient measure of control, to record an otherwise unattended operation where observation is necessary but immediate observation is impractical, and to record televised instructional programs for analysis or future use. When a permanent recording or many copies of the recording of the televised signal are required, film is often used in preference to magnetic tape.

5-52. *Equipment.* A kinescope recorder must be capable of synchronization with the television monitor and of resolving the timing differences between it and the television monitor. The camera exposure time must be controlled very accurately and synchronized with the television system. Special equipment has been developed to meet these requirements. Equipment required for accomplishing a motion picture film recording of the presentation shown by a television monitor includes (1) a television monitor (a high-intensity short-persistence cathode-ray tube), (2) a recording motion picture camera (usually 16mm), and (3) the equipment for recording the sound simultaneously with the picture.

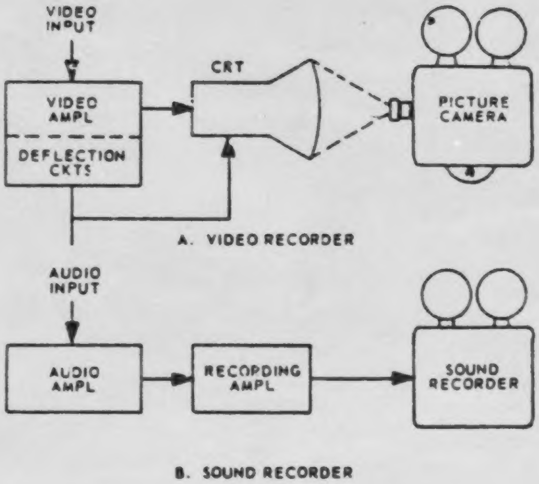


Figure 31. Elements of a kinescope recording system.

5-53. Figure 31 shows a television recording system consisting of both picture and sound recording channels employing separate cameras and film for each operation. The video recording channel consists of a suitable video amplifier, deflection circuits, a cathode-ray tube, and the film camera. The sound recording channel consists of a suitable audio amplifier, a recording amplifier, and the sound recorder itself.

5-54. As you can see, video recording is a combination of the techniques of television electronics and photography. (Electronic techniques will be covered in paragraphs 5-58 through 5-67.) A brief discussion of pertinent photography terms and techniques is considered to be appropriate and is included at this point.

5-55. Sensitometry is the measurement of the light response characteristics of photographic film under specified conditions of exposure and development. Gamma is the ratio of the contrast of any two elements in the scene being televised; gamma control (or correction) is accomplished by the introduction of nonlinear output-input characteristics which change the effective value of gamma. A good print requires a good negative with maximum gradation—a gradual shading of one tint, tone, or color into another.

The gray scale of the negative is the result of (1) time and intensity of exposure and (2) time, temperature, and concentration of the developer.

5-56. The same requirements must be met in order to produce a satisfactorily bright kinescope recording. The time of film exposure is determined by the television frame rate, whereas the intensity of light is controlled by the brilliance of the scene on the face of the cathode-ray tube and by the opening of the lens (f/stop). The intensity of light is influenced by the region of operation on the characteristic curve of the cathode-ray tube; the amount of light reaching the film is determined by the lens opening (f/stop) of the camera.

5-57. Development of the film is as important as its exposure and must be fully controlled. The contrast ratio of a developed film is expressed in terms of light transmission of the film after it has been developed. The determination of optimum operating levels for contrast in film recording involves considerable initial testing. Once the optimum settings are made, they are used continuously. However, periodic checks of film results should be made to determine what, if any, readjustments should be made. The test strip method of evaluating operation is desirable because it permits a rapid check of the various adjustments in the shortest period of time. Great care must be taken that developer concentration, age, and temperature are controlled. Operation and service manuals for the video recording monitors include detailed instructions for making strip tests.

5-58. *Video recording.* We have discussed some of the equipment and photographic requirements for kinescope recording. A very important requisite of video recording is that the exposure time of the recording camera must be very accurately controlled and synchronized with the television system. Let us now discuss the synchronization process.

5-59. The time of film exposure is determined by the television frame rate. This rate in the United States is 30 frames per second, whereas the standard motion picture projector frame rate is 24 frames per second. This means that all television recordings made on motion picture film require conversion of 30 television frames to the standard 24 motion picture frames. At the 24-frame-per-second rate, 6 television frames out of the 30 which occur every second must be discarded. The time interval represented by these 6 television frames may be used to provide the necessary pulldown time in the television recording camera. The problem of reconverting from the standard 24 motion picture frame rate to the 30 television frame rate, when projecting a motion picture film on television, will be covered in the discussion of 16mm film projectors (paragraphs 6-2 through 6-5 of this chapter).

5-60. Figure 32 shows a possible conversion time relationship between television field, recorded film frames, and film pulldown. Note that each television field has a duration of 1/60 sec-

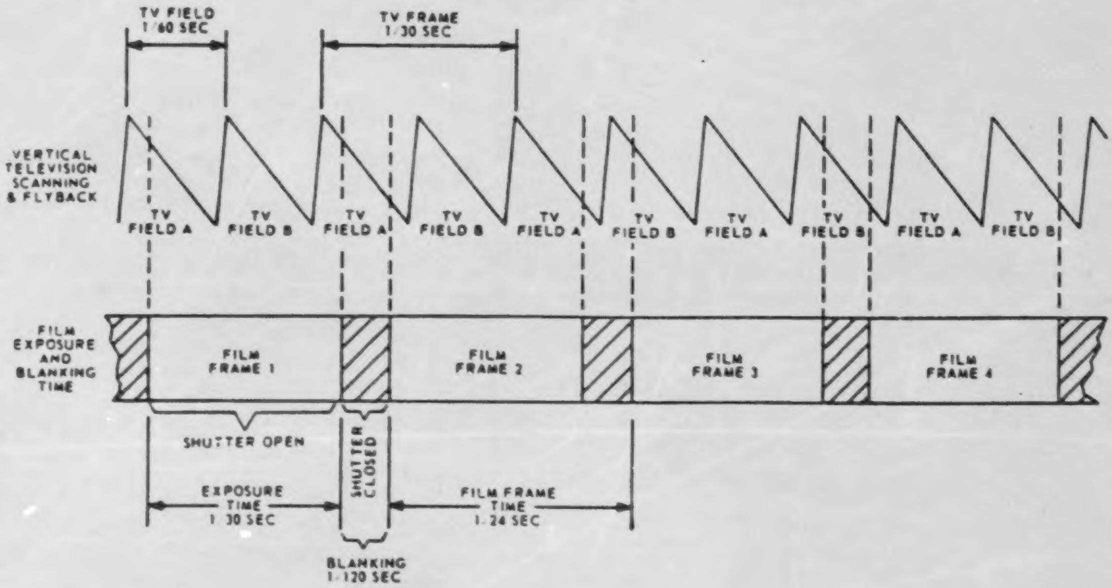

TV FIELD 1/60 SEC
TV FRAME 1/30 SEC
VERTICAL TELEVISION SCANNING & FLYBACK
TV FIELD A
TV FIELD B
TV FIELD A
TV FIELD B
TV FIELD A
TV FIELD B
TV FIELD A
TV FIELD B
TV FIELD A
TV FIELD B
FILM EXPOSURE AND BLANKING TIME
FILM FRAME 1
FILM FRAME 2
FILM FRAME 3
FILM FRAME 4
SHUTTER OPEN
SHUTTER CLOSED
EXPOSURE TIME 1/30 SEC
FILM FRAME TIME 1/24 SEC
BLANKING 1/120 SEC

Figure 32. Conversion time relationship between television scanning and film exposure.

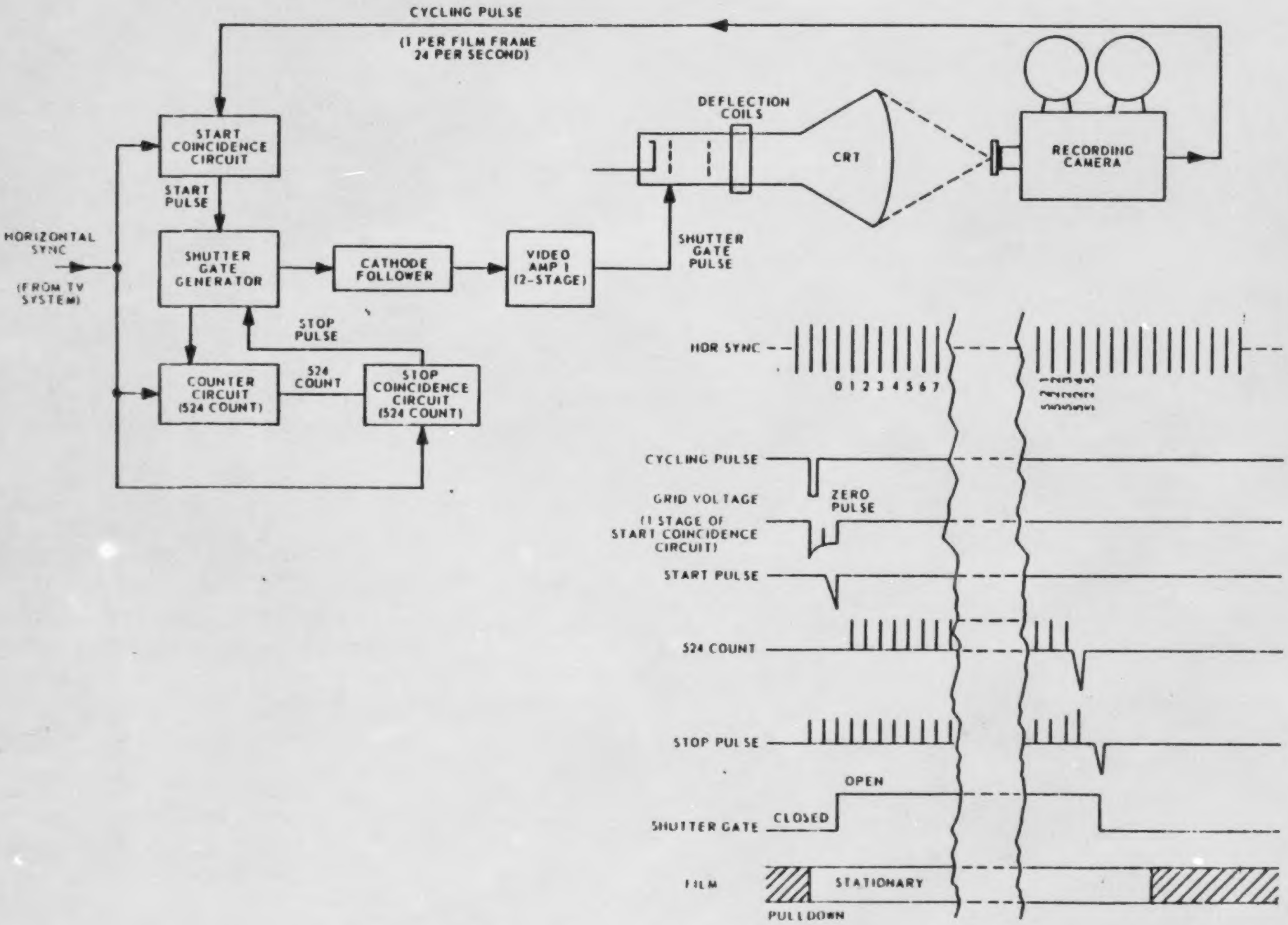

CYCLING PULSE
(1 PER FILM FRAME 24 PER SECOND)
START COINCIDENCE CIRCUIT
START PULSE
HORIZONTAL SYNC
(FROM TV SYSTEM)
SHUTTER GATE GENERATOR
CATHODE FOLLOWER
VIDEO AMP I (2-STAGE)
SHUTTER GATE PULSE
DEFLECTION COILS
CRT
RECORDING CAMERA
STOP PULSE
COUNTER CIRCUIT (524 COUNT)
524 COUNT
STOP COINCIDENCE CIRCUIT (524 COUNT)
HOR SYNC
0 1 2 3 4 5 6 7
CYCLING PULSE
GRID VOLTAGE (1 STAGE OF START COINCIDENCE CIRCUIT)
ZERO PULSE
START PULSE
524 COUNT
STOP PULSE
OPEN
SHUTTER GATE
CLOSED
FILM
STATIONARY
PULLDOWN

Figure 33. Electronic shutter block diagram.

ond and each frame has a duration of $^{1}/_{30}$ second, whereas each motion picture frame has a duration of $^{1}/_{24}$ second. Let's analyze the operation which accomplishes the desired conversion. A motion picture camera capable of pulling the film down within the available time interval is focused upon the television image on the face of the television monitor. With film in the camera aperture, the shutter is permitted to open while the picture tube beam is tracing one field of the television picture—figure 32 shows a TV A field being scanned first. The shutter is permitted to remain open for the remainder of that A field's scanning time, plus one B field's scanning time, plus the portion of the next A field's scanning time—which is exactly equal to the lost (blanked) portion of the initial A field's scan. The shutter is then closed for $^{1}/_{120}$ second. The motion picture film is pulled down to the next frame while the shutter is closed. During this interval the picture tube's scanning beam has continued on its way and has scanned down to approximately three-fourths of the A field on which the shutter closed. The shutter again opens and the camera photographs the remaining lower portion (approximately one-fourth) of this A field, the whole of the next B field, and a top portion of the next A field. Note that the top portion of this last A field is equal to the previous A field's scanning time minus the portion picked up by the camera when the shutter opened. Again, the shutter closes for $^{1}/_{120}$ second and the film is pulled down to the next frame. The shutter again remains open for $^{1}/_{30}$ second (the time of two television fields) and then closes. If you follow the action as illustrated in figure 32, you will see that two half fields out of every five fields scanned by the television process are not photographed. This is the same ratio as 6 fields out of every 30 fields; thus, the required conversion of 30 television frames to 24 motion picture frames is accomplished.

5-61. Since a portion of one television field is discarded during pulldown for the recorded field, some means of preventing film exposure during pulldown must be provided. This may be accomplished by either a mechanical or electronic shutter which performs the cyclic steps of starting, stopping, and timing each film exposure. Our discussion is limited to the electronic shutter.

5-62. Shutter action and pulldown action must be correctly timed with respect to each other. Figure 33 is a block diagram of the circuits comprising a typical electronic shutter together with a timing diagram. The diagram shows a shutter gate generator that is blanking the cathode-ray tube during a portion of the film cycle. The phasing and timing of the shutter gate are established by associated electronic circuits. One of these circuits opens the gate and starts the timing action as soon as pulldown of the preceding exposed frame has been completed. Another circuit times the exposure, and a third circuit closes the gate.

5-63. Counting circuits are used to time the film exposure. Their use is possible since each television frame contains exactly 525 horizontal scanning lines. The counting circuits blank the cathode-ray tube after the correct number of horizontal lines have been scanned. The film exposure may be initiated on any horizontal line. Once started, it continued until completion of the television frame and then stops until triggered by a cycling pulse. Camera film pulldown starts after the exposure stops. When pulldown is completed and the film has become stationary, the camera generates the cycling pulse which starts a new cycle. The cycling pulse is an electronic pulse initiated by a mechanical timing sequence.

5-64. The output of the start coincidence circuit is the start pulse, which initiates film exposure. It is a two-stage stable circuit with one tube conducting heavily and the other tube biased below cutoff. The cycling pulse is applied to the start coincidence circuit and the conducting tube is cut off; its grid voltage instanteously reaches maximum negative value and then begins its buildup action. However, this action does not initiate the actual exposure. Horizontal synchronizing pulses (one per horizontal scanning line) are also applied to the start coincidence circuit. Within the time of a few scanning pulses, the grid voltage of the cutoff tube rises sufficiently for one of the synchronizing pulses to trigger the circuit. As stated earlier, this synchronizing pulse may lie anywhere in the scanning cycle; it becomes the start pulse, which opens the shutter gate.

5-65. The shutter gate generator is a two-stage circuit which has two stable conditions characterized by conduction of one or the other of the two tubes. It has two outputs, one of which is applied to the control grid of the cathode-ray tube. Before the start pulse is received, a negative output blanks the cathode-ray tube (shutter gate is closed). The start pulse reverses the stable condition of the circuit, causing a positive output to unblank the cathode-ray tube (open the shutter gate) and camera film exposure action to begin. The exposure action is continuous until a television frame is completed. Upon completion of the television frame, a stop pulse from the stop coincidence circuit is applied to the shutter gate generator and its output blanks the cathode-ray tube, thus stopping the exposure action until another cycling pulse is received.

5-66. The other output from the shutter gate generator is applied to the counting circuit. Horizontal synchronizing pulses are also applied to the counter circuit. The shutter gate output which is initiated by the start pulse begins the counter action. The counter circuit includes ten counter stages consisting of two diode sections each. Its operation is similar to that of a conventional binary counter, with combinations of connections between each reset diode and its associated counter diode made in such manner that, when the overall circuit count of 524 incoming pulses is reached, an output pulse is generated (see upper left, fig. 33).

5-67. The output pulse from the counter circuit is applied to a stop coincidence circuit. The stop coincidence circuit is similar to the start coincidence circuit, with the 524 count pulse taking the place of the start pulse as one of the inputs. The other input, the string of horizontal synchronizing pulses, is the same. The output is the stop pulse. The stop coincidence circuit contributes the 525 count. It stops both the exposure action and the timing action. Again, camera film pulldown starts. When pulldown is completed and the film has become stationary, the camera generates another cycling pulse which starts a new cycle.

5-68. *Sound recording.* Sound recording of television programs on magnetic tape was discussed earlier in this chapter. The sound portion of a television program may also be recorded on motion picture film. In kinescope recording, the sound portion and video portion of the program are recorded simultaneously. Either the single-film system or the double-film system of recording may be used. In the double-film method, separate motion picture cameras are used to record the video and sound portions of the television program on separate films. In the single-film system, video and sound are recorded simultaneously and the audio output of a recording amplifier is fed to the film camera, rather than to a separate sound recorder. In either system, appropriate conventional audio amplifier circuits may be used. A sound track varying in either area or density is photographed on motion picture film. The density or area variations in the sound track are directly proportional to the amplitude of the incoming audio signal.

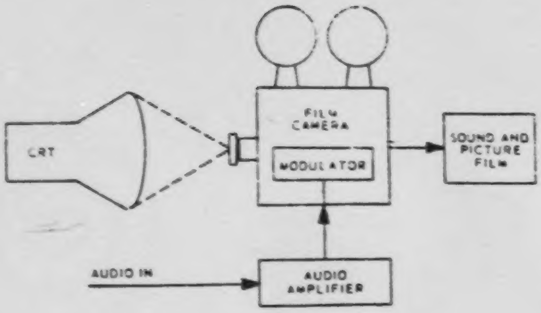


Figure 34. Single-film television recording system.

5-69. Figure 34 is a block diagram of a single-film system of television recording. The single-film system usually utilizes a galvanometer modulator unit which records a variable density photographic sound track on the film. A mirror is attached to the galvanometer. As the galvanometer fluctuates with the audio signal, the mirror changes its position and varies the amount of light reaching the film. This results in a variation in density exposure of the sound track.

5-70. *Video and sound synchronization.* In the single-film system the sound track is photographed on one side of the picture track, between one set of sprocket holes and one edge of the picture. The film must be stationary when video tape is exposed; however, the film must move continuously to expose the sound film. Each camera has its own film loading diagram or guide which must be followed for satisfactory recording. The film loops are especially critical. When sound and video signals are simultaneously recorded, the sound record precedes the video record by 26 film frames. The bottom film loop is exactly 26 frames in length. This loop permits the film to move continuously around the sound recording drum. Deviation from this 26 film frame length loop results in a lead or lag of sound in reference to the picture when the composite television signal is reproduced. The upper film loop permits continuous motion of the film from the camera during intermittent film pulldown. If this loop is too short, the video will jump or flutter when reproduced. (For further information concerning reproduction problems, refer to the troubleshooting chart for 16mm film projectors shown in paragraph 6-22 of this chapter.) In the double-film system of television recording, synchronization of the video and sound signals is usually accomplished by employing synchronous motor drives in both units.

5-71. *Maintenance requirements.* Since kinescope recording requires critical synchronization of the television monitor and the camera recording equipment, it is important that optimum operational standards be maintained for all mechanical and electrical operations. Detailed instructions for operational checks are included in the manuals of operation which are furnished with each kinescope recorder. The instructions should be followed carefully.

5-72. The television monitor should be installed so that it is free of vibration and floating properly on its shock mounts to prevent distortion. There never should be anything jammed under it nor placed on top of it. Cathode-ray tube and cable installation instructions should be observed carefully. For best recording results, periodic checks are necessary to determine certain optimum operating levels. Once established, the settings are used continuously. However, because aging of components (particularly in the cathode-ray tube) causes optimum settings to change slowly with time, film results should be checked periodically to determine which, if any, readjustments should be made.

5-73. Since critical tolerances must be observed in all servicing procedures other than simple adjustments to the recording camera, the camera should be returned to the factory when such servicing is considered necessary. For this reason, your major responsibilities for the maintenance of the kinescope recorder will consist of preventive maintenance. Neglect of camera equipment may cause cumulative minor damage, which can result in loss of operating time. The interior of the film compartment should be cleaned frequently with a clean, lint-free cloth and a soft brush. All sprockets and pad rollers should be inspected for dust, nicks, and other damage. Any foreign matter should be moved with a soft brush. Since the pad rollers must be free to rotate easily, occasional lubrication is necessary. The cam-claw mechanism requires frequent lubrication. The lens should be removed and cleaned with a lens tissue. (Procedures for cleaning lens surfaces are discussed in paragraph 2-23, Section 2, Chapter 1 of this volume.) Caution should be taken to insure that the lens is returned to its exact position and reset to the proper focus and f/stop.

5-74. The galvanometer modulator unit must be kept clean. The covers should be opened only when necessary and closed immediately thereafter. When the unit is out of the camera, the front lens should be covered. Under no circumstances should the mask be exposed, because it readily collects dirt and dust. The lamp may be cleaned by breathing on it and wiping it with a lint-free cloth. The lamp should be replaced when the filament sags or the envelope begins to darken.

5-75. We cannot overemphasize the importance of observing proper film loading procedures. Improper loading of the camera film is manifested in undesirable results, such as film damage, picture unsteadiness, and improper synchronization of picture and sound.

6. Projectors

6-1. Both moving film projectors and slide projectors will be discussed in this section. The 16mm and 35mm moving film projectors will be compared, showing the relative advantages and disadvantages of each machine. Conversion of the film frame rate to the television frame rate will be included and should be of special interest to the maintenance technician. The maintenance requirements, troubleshooting procedures, physical characteristics, and other special features of the 16mm film projector will be explained. (You may wish to review Chapter 1 of this volume for an explanation of the operating characteristics of rear screen projectors.) The more intricate features and complex component arrangements peculiar to slide projectors employing dual optical systems will be our major concern in this section.

6-2. **16mm Projectors.** The standard 16mm film projector and the 16mm film projector used in television differ in three basic criteria. First, the standard projector has a frame rate of 24 frames per second (fps), whereas the television system, as previously explained, operates at 30 frames per second (fps). Since this difference exists, some means of conversion from the 24 frame projection rate to the 30 frame television rate must be devised. Second, while the standard projector needs no synchronization, a projector used in television must be synchronized with the camera to insure their sequential operation. Third, the projection cycle of the television film projector must be adaptable to peculiar needs and applications. Some projector requirements peculiar to television concern the lens and audio specifications. The projector lens must have a short throw (focal length) and moderate magnification factor. The sound system must be compatible with live programming.

6-3. *Flicker reduction.* The standard 16mm projector uses a frame rate of 24 fps, with each frame being interrupted twice, once for film pulldown and once to increase the flicker frequency. This creates a flicker frequency of 48 times per second, which is much less noticeable to the human eye and gives the appearance of a constant image. At this frequency each showing of the frame may be considered as a field. However, as stated earlier, the television scan rate is 30 frames per second or 60 fields per second; thus a conversion problem exists.

6-4. *Conversion from 24 to 30 frames per second (fps).* One solution to conversion is the use of an intermittent film pulldown and shutter mechanism in conjunction with a storage type pickup tube. Light is flashed on the pickup tube

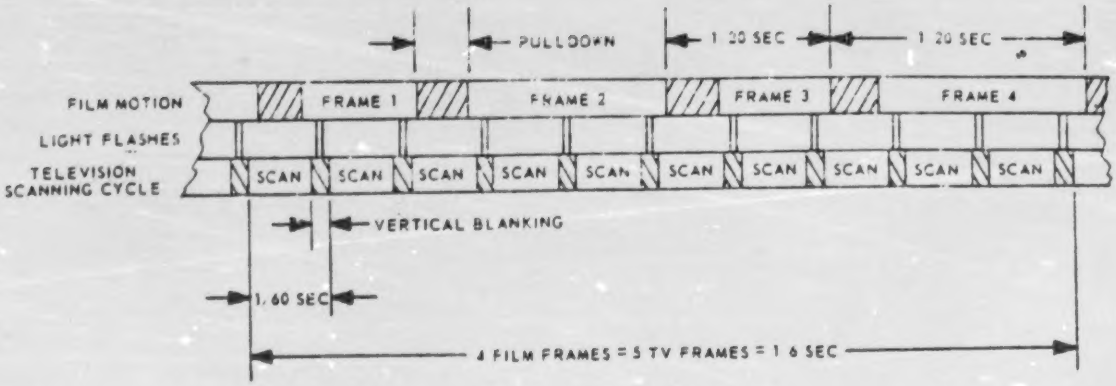


Figure 35. Time cycle of a typical film projector.

only during the vertical retrace time, and the tube's photosensitive element retains the image long enough for scanning during the following dark period. By referring to figure 35 we see that the film picture frames are moved through the projector in alternate steps of $1/30$ and $1/20$ second, maintaining the necessary $1/24$ second average. Actual pulldown occurs between light flashes, and the pickup tube is illuminated alternately two and three times per picture frame. Note that the sequence of pulldown for four picture frames takes the same time ($1/6$ second) as is needed for 10 television scans of 5 television frames; thus, the two systems are made synchronous—i.e., 60 pictures or 30 television frames are completed each second, while the average speed of the film remains at 24 frames per second.

6-5. Converting the 24 frame rate to the 30 frame rate is accomplished with a specially designed intermittent. The intermittent has a three-sided geneva movement which pulls the film down for unequal time intervals. Alternate frames dwell in the film gate $1/60$ second longer than the preceding and following frames. Light pulses of very short duration ($1/1200$ second), recurring 60 times per second, flash twice through the first frame, three times through the second, twice through the third, three times through the fourth, etc. Scanning begins immediately at the end of each light flash and completes itself while the film is not illuminated. The action just described is possible because of the storage properties of the pickup tube.

6-6. *Projector synchronizing.* As mentioned earlier, television film projectors require synchronization. To insure proper sequential operation, the shutter and intermittent pulldown drives must be phased and locked together. Further, to insure simultaneous operation of the projector and television scanning process, the projector, television camera, and synchronizing waveform generator must be locked and phased together.

6-7. The synchronization process normally is accomplished by using a unique-phase synchronous motor to drive the projector. The synchronizing waveform generator and the unique-phase synchronous motor are simultaneously locked to the a-c power supply. The unique-phase synchronous motor satisfies two definite requirements: (1) it is designed to lock to the a-c line frequency; (2) the rotor and field coils are wound to permit only an in-phase line lock. An ordinary synchronous motor can be used in lieu of the unique-phase synchronous motor, provided care is exercised to insure its operation in phase with the line frequency. These precautionary measures are necessary because the ordinary synchronous motor can be operated in phase with or 180° out of phase with the a-c line frequency. If operation of the synchronous motor is 180° out of phase with the a-c line frequency, the image will be projected while the picture is being scanned. Notice in figure 35 that the light is applied only during vertical blanking. For both the unique-phase and ordinary synchronous types, motor design is such that little change in torque angle occurs under varying load conditions during film and projector operation.

6-8. Use of a unique-phase synchronous motor is unnecessary when a pulsed light or flash tube is used in the projector. In this situation an ordinary synchronous motor may be used to drive the projector because there is no shutter and the light source is controlled by the synchronizing waveform generator. Since the light is controlled by the synchronizing waveform generator and is not dependent upon a motor or the a-c power supply frequency, the light flashes are always in the proper phase.

6-9. Regardless of the type of synchronous motor used, the phase relationship between the

FILM TYPE	RUNNING TIME MINUTES AND LENGTH				
	1 MIN	15 MIN	30 MIN	60 MIN	90 MIN
35MM	90 FT	1350 FT	2700 FT	5400 FT	8100 FT
16MM	36 FT	540 FT	1080 FT	2160 FT	3240 FT

Figure 36. Comparison of running time length, 16mm-35mm film.

projector and synchronous waveform generator is very critical. However, this requires adjustment only during the original installation, unless a major malfunction or slippage occurs.

6-10. *Projector adaptability*. In terms of film capacity the 16mm film projector is much more adaptable than the 35mm projector and satisfies the needs of television to a greater degree. A comparison of running times and film lengths (see fig. 36) readily demonstrates the advantages of the 16mm projector. Since much of the television programming time consists of an hour or more in length, the 4000-foot (approximately 1 hour and 45 minutes) film capacity of the 16mm projector more fully meets most television requirements. Other factors besides limited film capacity restrict the use of 35mm projectors—e.g., bulk storage, weight, and city ordinances restricting the length of 35mm film. Safety is still another factor resulting in the more extensive use of 16mm film and 16mm projectors. All 16mm film is a safety base film.

6-11. The type of pulldown mechanism may also affect the adaptability of the television film projector. The sprocket or claw intermittent pulldown mechanism may be used. Selection of the type of intermittent depends upon the features most desired in the projector. The most significant advantage of the sprocket intermittent is its ability to help increase film life. The claw intermittent, however, is the most widely used because of its capacity to handle damaged and spliced film. Also, use of the claw intermittent makes possible the restoration of a lost film loop.

6-12. The projector optical system is designed to achieve maximum resolution (a minimum acceptable resolution standard is 600 lines). Thus, the projector does not limit the overall resolution of the television system. Light efficiency of the optical system is also an important consideration. A projector designed for high light efficiency, while using a smaller light source, can produce light equivalent to a standard film projector. The projector should produce a uniform flat field of light (less than 10 percent variation) over the entire picture area.

6-13. Ease of threading, an important feature to be considered when selecting a projector, is determined, to a large extent, by component location. Figure 37 shows the general arrangement of components and the film path. Note that ample space is provided to permit easy placement of the film around the sprockets and into the film gate, thus facilitating film reel change when using multireel film.

6-14. The projector selected for television use should be both stable and reliable under continuous operating conditions. Projector stability covers two general areas: (1) its construction should be solid and free from movement in any direction, and (2) picture stability and constant film speed are important factors in minimizing picture jitter. Proper lateral guidance compensates for dimensional errors in the film and eliminates horizontal weave and unsteadiness.

6-15. *Lens*. The moving film projector, as previously stated, requires a lens with a short throw (focal length) and moderate magnification. Since the film projector casts the image directly upon the camera pickup tube, the lens focal length is determined by the distance between the camera and projector. This distance is seldom more than a few feet. The magnification factor is determined by the size of the camera pickup tube, which in turn dictates image size. These focal length and magnification requirements also apply when using a multiplexer.

6-16. *Compatibility of the audio system*. The film audio must have good frequency response and tonal quality to insure compatibility with live television programming. To achieve these qualities, the film is passed over the sound drum at a constant velocity. A pressure roller is employed to maintain a fixed plane for the film while moving over the sound drum. Note the film loop between the film gate and sound drum in figure 37. This loop of film and the balanced flywheel compensate for the sporadic operation of the intermittent pulldown mechanism. These features help eliminate film flutter and instability, which, if not eliminated, cause wowing and fluctuation in the audio output.

6-17. *Maintenance requirements*. With some additions, the maintenance requirements of moving film projectors are much the same as those previously discussed for rear screen projectors. However, there are more moving components in a film projector than a slide or rear screen projector; thus the lubrication procedures are much more detailed.

6-18. Lubrication of motors and assemblies, such as the shutter motor, the blower motor, the takeup assembly, the flywheel drive assembly, and the gear boxes, must be accomplished at

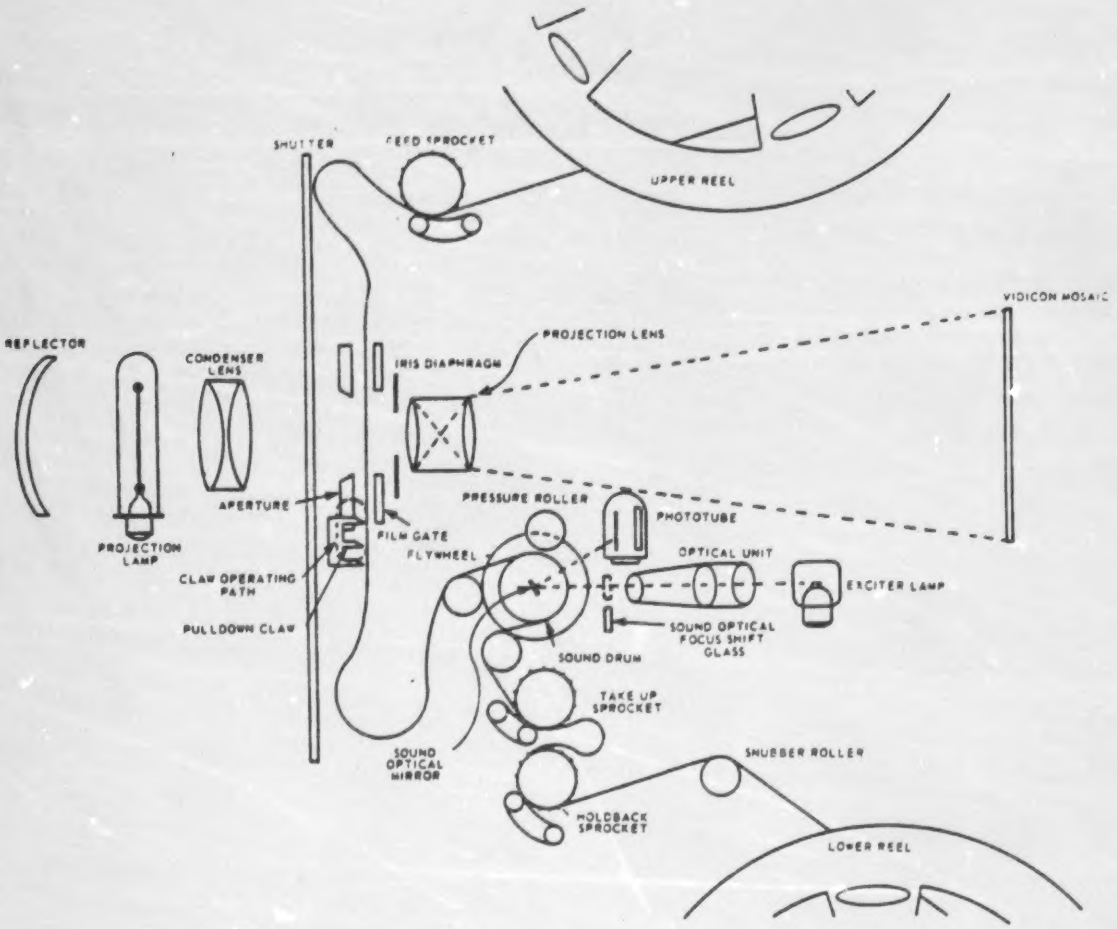

SHUTTER
FEED SPROCKET
UPPER REEL
VIDICON MOSAIC
REFLECTOR
CONDENSER LENS
PROJECTION LENS
IRIS DIAPHRAGM
APERTURE
PRESSURE ROLLER
PHOTOTUBE
PROJECTION LAMP
FILM GATE
FLYWHEEL
OPTICAL UNIT
EXCITER LAMP
CLAW OPERATING PATH
PULLDOWN CLAW
SOUND OPTICAL FOCUS SHIFT GLASS
SOUND DRUM
TAKE UP SPROCKET
SOUND OPTICAL MIRROR
SNUBBER ROLLER
HOLDBACK SPROCKET
LOWER REEL

Figure 37. Optical principles and movement of film in 16mm film projector.

periodic intervals. Use of the proper lubricant is important. Since several types are used, the manufacturer's handbook or appropriate technical order should be consulted before starting these tasks.

6-19. Many types of cleaning agents and materials are necessary for different projector sections. Lens tissue must be used when you clean such areas as the sound optical unit, the sound optical mirror, filters, condenser lens, and the projection lens. You must also exercise caution when working near the sound optical mirror, since touching it with material other than lens tissue may cause permanent damage. Since other projector components, such as the rollers, sprockets, and sprocket shoes, will withstand more punishment, you may use a brush and cleaning solvent to clean these sections. The sound drum and pressure rollers also may be cleaned with a soft, lint-free cloth.

6-20. Several components in the moving film projector are adjustable, but again the appropriate instruction manuals should be consulted before the adjustments are performed. Adjustments of components such as pulldown intermittent, frame stop, sound optical unit, and sprocket shoe are very critical; therefore, extreme care must be exercised when making adjustments in these areas. Although adjustments of the idler gear, pressure roller, and damper roller are less critical, adjustments in these areas should nonetheless be made with caution.

6-21. Because wow and flutter are inherent problems in moving film projectors, periodic tests must be made to prevent their occurrence. The frequency response and overall audio reproduction quality must be checked to insure optimum projector operation. Specially produced film strips are available for performing these quality checks.

6-22. *Troubleshooting.* Many of the common troubles, with possible causes, which may confront you are listed below:

- Loss of lower film loop—Torn sprocket hole in film, film binding in the gate, dirt on claw, or bad spices.
- Loss of upper film loop—Film improperly threaded on upper sprocket.
- Picture unsteady—Improper threading of projector, emulsion on film pressure shoe, or emulsion on aperture plate.
- Picture illumination low—Dirty projection lens, dirty condenser lens, or dirty reflector.
- No audio—Improper threading, dirt blocking light, or tube failure in amplifier.
- No projected image—Projection lamp burned out.

Some of the more complex problems may have the same symptoms as those indicated in the list. For instance, loss of the lower film loop can also indicate that the pulldown claw is out of adjustment, the claw and aperture plate are touching, or the cam travel is insufficient. An unsteady picture could indicate causes other than those listed; for example, improper claw adjustment, worn claw teeth, worn intermittent cam, or weak side pressure springs. These two examples merely point out some trouble symptoms which may indicate either major or minor problems.

6-23. **Slide Projectors.** Several types of slide projectors may be employed in a single television system. Since all slide projectors operate on the same principle, we will discuss the most versatile of these. The slide projector's versatility is determined by its design and construction. In other words a slide projector with dual optical paths, dual slide magazines, preview facilities, and dual lighting features is much more adaptable to changing requirements than a slide projector with only a single optical path, single light source, and limited slide capacity. In this section we will discuss the overall requirements, characteristics, function, and operation (electrical and mechanical) of the more complex slide projectors.

6-24. *Function.* Slide projectors, as applied to television, are generally used to support a program script. This function may be accomplished in many ways. An image may be projected directly upon the face of the camera pickup tube, or when more than one projector is used, into a multiplexer. Other production needs may require that the image be projected upon a projection screen from either the front or rear (as discussed in Chapter 1 of this volume). However, in this section we are primarily concerned with slide projectors which project the image directly upon the camera pickup tube.

6-25. *Requirements.* The projector pedestal or base must be constructed to prevent undesirable movement, since movement of the slide projector itself will be magnified in the projected image. The slide projector must also be designed to permit continuous operation for extended periods of time. Component size, location, and durability are important features to be considered from the maintenance viewpoint. The size and location of the slide projector's components will determine the ease with which maintenance can be performed. The durability of each component will determine its failure rate, which in turn will determine the slide projector's reliability and consequently its maintenance requirements. Like the 16mm film projector, the slide projector will probably be located in close proximity to the camera pickup tube. Consequently, the lens requirements (focal length and magnification factor) are consistent with those for 16mm film projectors, as discussed in the previous portion of this section. Other requirements, such as uniform flatness of the image field, light efficiency, and a minimum of 600 lines of resolution, are equally as important in slide projectors as they are in 16mm film projectors.

6-26. *Characteristics.* Since many of the slide projector characteristics are related to its requirements and were mentioned only briefly, we will develop those areas more fully at this time. The areas we are primarily concerned with are projector flatness of field, light efficiency, minimum resolution standards, lens focal length, and magnification features. The slide projector, to be compatible with another projector, must have the same characteristics. Since this is true, the slide projector must have the same characteristics as all the other projectors when they are to be used interchangeably or multiplexed. Thus, these five characteristics must be the same for the slide projector as those discussed for 16mm film projectors.

6-27. The uniform flatness of the image field of slide projectors like that for moving film projectors should not be less than 90 percent. That is, light intensity through the dark scenes should be no more than 10 percent less than that through light scenes.

6-28. Light efficiency of the slide projector is determined to a large extent by the condenser lens. The condenser lens collects the light and concentrates it upon the slide area. Thus, the slide projector can operate satisfactorily with a smaller light source with less heat and damage resulting from high operating temperatures.

6-29. The resolution requirements for slide projectors used in television must meet a 600-line standard. Thus the slide projector will not be a limiting factor on the rest of the television system's resolution. The projection lens of a slide projector must have a short throw because of the short distances between the projector and camera pickup tube. Inasmuch as the image is projected upon the face of the camera pickup tube, the magnification factor of the projection lens must be small.

6-30. *Electrical operation.* The slide projector employing dual optical paths may use an electrical means for transferring light from one path to the other. The easiest way of accomplishing this electrically is to use two projection lamps, one for each optical path. When one optical path is in use, its projection lamp is turned on and the projection lamp for the other optical path is turned off. As the optical paths are changed the slide is also changed. The projection lamp used for the first optical path is turned off and the projection lamp for the second optical path is turned on. Although the side projector employing a dual optical system and this type of light transfer is much more versatile than a slide projector employing a single optical path, one great disadvantage presents itself. Before the second projection lamp can be turned on, its filaments must be preheated to prevent damage. The time necessary to preheat the projection lamp filaments produces a time lag between slide changes; thus the program continuity is destroyed to some extent. Another electronic device which will improve the projector versatility is a remote control switch. The projector operator can then remotely turn the projector on or off and change slides in either direction.

6-31. *Mechanical operation.* A second and much more efficient means of transferring light from one optical path to the other is accomplished with a sliding mirror. This method of transferring light can be done either electrically or mechanically, and many slide projectors of this type will employ both methods. The operator then may make the decision as to which method is best for any given program need. The greatest advantage of transferring light with a sliding mirror is the instant display of the new image. Figure 38 illustrates a slide projector with dual optical paths and a sliding mirror for light transfer from one path to the other.

6-32. The two laws of mirror action as they apply to rear screen projectors (discussed in Chapter 1) also apply to mirrors when used with projectors having dual optical paths. As you will probably remember, these laws simply state that the angles of incidence and reflection are equal and the incident, normal, and reflective rays all lie in the same plane

6-33. *Maintenance.* The maintenance procedures for slide projectors with dual optical systems are similar to those pertaining to rear screen and 16mm moving film projectors. As discussed in the rear screen and 16mm film projector sections, the primary maintenance functions are cleaning, inspection, lubrication, and adjustment. These functions should be accomplished at periodic intervals in the manner prescribed by the

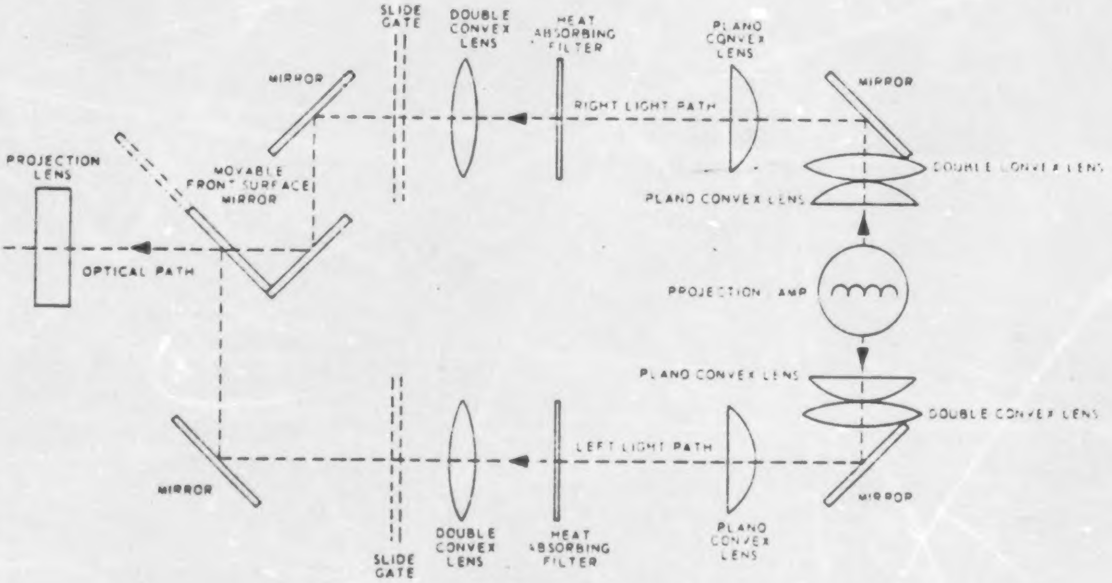

SLIDE GATE
DOUBLE CONVEX LENS
HEAT ABSORBING FILTER
PLANO CONVEX LENS
MIRROR
MIRROR
RIGHT LIGHT PATH
PROJECTION LENS
MOVABLE FRONT SURFACE MIRROR
DOUBLE CONVEX LENS
PLANO CONVEX LENS
OPTICAL PATH
PROJECTION LAMP
PLANO CONVEX LENS
DOUBLE CONVEX LENS
LEFT LIGHT PATH
MIRROR
MIRROR
SLIDE GATE
DOUBLE CONVEX LENS
HEAT ABSORBING FILTER
PLANO CONVEX LENS

Figure 38. Slide projector dual optical system

appropriate TO or maintenance instruction manual.

6-34. Cleaning of all lenses, mirrors, and glass surfaces is accomplished with approved cleaning materials, since other materials may cause permanent damage to these components. Inspect each slide projector at prescribed time intervals. Look for damaged, broken, burned, or loose components, connectors, and interconnecting cables. If you discover any discrepancies, repair or replace immediately. All slide projector moving parts or components require lubrication. Refer to the appropriate TO or maintenance instruction manual and use the recommended lubricant or a suitable substitute. Also, check and adjust the slide projector's position in relation to the camera pickup tube when necessary. Proper positioning is necessary to provide the best possible resolution, uniform image field, and prevent keystoning.

7. Vidicon Multiplexers

7-1. Multiplexers and multiplexing systems are used to mix several video inputs and produce one output for the camera. These systems may also select an input from one of several sources. Many methods are used to accomplish this effect. Some of the methods used are swivel or track mounted cameras and multiplexers with stationary mirrors, movable mirrors, or prisms. The most complex systems may employ any combination of the methods mentioned above. Each of the systems has its advantages and disadvantages; the method used depends entirely upon the requirements and available space of the individual television station. In this section we will be concerned primarily with vidicon multiplexers which employ different types of mirrors and mirror arrangements. We will discuss the mechanical considerations, operation, maintenance, and troubleshooting peculiar to vidicon multiplexers.

7-2. **Mechanical Considerations.** Since multiplexers and multiplexing systems are usually permanently mounted in a fixed location, they cannot be readily moved from place to place. The optimum performance of the multiplexer then depends upon the mechanical requirements, component characteristics, and component functions.

7-3. *Mechanical requirements.* Since the multiplexer system, unlike field and studio cameras, operates from a fixed location, it must be both rigidly constructed and solidly mounted to insure proper registration and focus of the projected image upon the face of the vidicon pickup tube. All mountings for movable components of the multiplexer must be exceptionally rigid to prevent vibration during operation.

7-4. The mirrors are made of heavy glass to prevent vibration and warping. Consequently, jitter and geometric distortion are reduced in the output presentation. The movable mirrors are mounted on bearings to permit smooth operation. The second surface coating of all front surface mirrors, whether movable or stationary, must have a low reflective quality, because high reflection from these areas produces undesirable spurious image reflections and ghost effect.

7-5. The multiplexer mirrors must be shielded from external light sources. This light should not be allowed to strike the mirrors directly since this too decreases the operating efficiency of the mirrors and produces spurious image reflections and ghost effect. The transmission of light between any input and the output must be the same if a free choice of projector arrangement is possible. The multiplexer and camera optics should be compatible with each other. Their optical paths should coincide to permit proper positioning of the image on the vidicon pickup tube and aid in maintaining the proper optical focus.

7-6. *Characteristics.* The multiplexer spectral characteristics should be neutral; thus the gray-scale balance will not be disturbed between the video channels. Mirrors with clear, precise, planar reflecting surfaces will not disturb the optical focus and uniform flatness of the image field between the camera and projector. Therefore, the characteristics of both front surface mirrors and semitransparent mirrors, as discussed for rear screen projectors (Chapter 1) and slide projectors (Chapter 2), also apply to the mirrors used in the multiplexing system.

7-7. Two inherent problems are encountered when projected images are not operated along coincident optical paths. The first, geometric distortion, has the greatest effect upon the video output. Second, jump and weave of the video display are apparent. Neither of these problems was of much importance in the original multiplexing systems where the iconoscope was used for video pickup. However, with the advent of the vidicon pickup tube, which is about nine times smaller than the iconoscope, they became major problems that necessitated the development of better multiplexing systems to reduce geometric distortion, jump, and weave to a minimum.

7-8. *Function.* The purpose and function of each component, such as lenses, mirrors, solenoids, and precision gear trains, will determine the versatility and flexibility of the multiplexer. The function of the field lens in the multiplexer, as illustrated in figure 39, is to form an intermediate image between the projection lens and the camera lens. The projected image will then re-

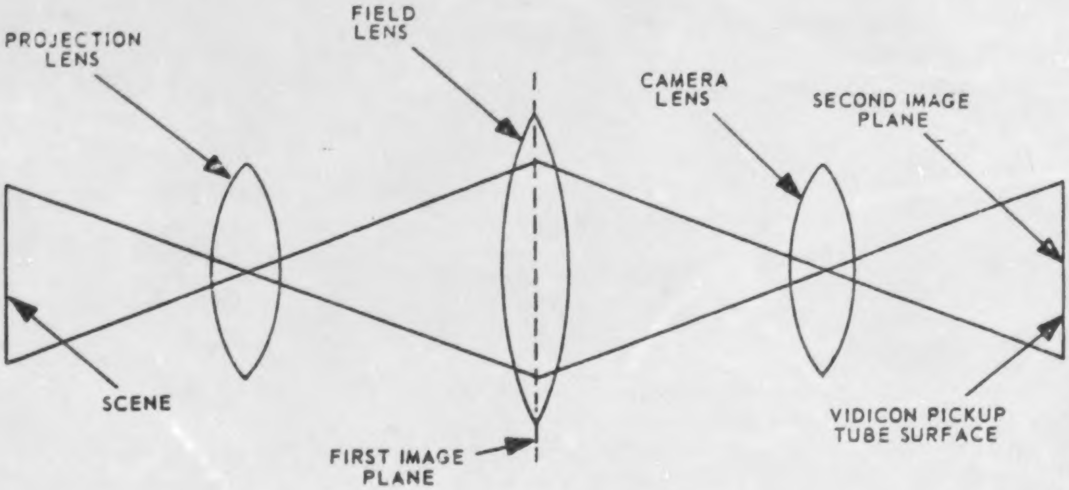

FIELD LENS
PROJECTION LENS
CAMERA LENS
SECOND IMAGE PLANE
SCENE
VIDICON PICKUP TUBE SURFACE
FIRST IMAGE PLANE

Figure 39. Field lens projection system.

main true in perspective through the multiplexing unit.

7-9. Many means of selecting the optical path may be employed. The most common method uses front surface full reflecting mirrors and semitransparent mirrors. These mirrors may be either stationary or movable, depending upon the versatility and flexibility desired. Figure 40 shows a multiplexer containing a single, fixed semitransparent mirror which is capable of mixing two projector inputs and reflects one output to the camera pickup tube. You can see from the illustration that the mirror directs the image from the projector to the camera pickup tube.

7-10. Multiplexers of a more complex design which use movable mirrors in their operation will also use solenoids to operate the precision gear train. Solenoids, being electrical switches, can be operated remotely; hence, the optical path may be changed from a remote location. Precision gear trains are used to operate smoothly the mirror assemblies and reduce resultant vibrations which may otherwise destroy the alignment of the optical paths.

7-11. **Operation.** The simplest type of multiplexer may employ a single front surface mirror to direct the projected image onto the camera pickup tube mosaic. The simple multiplexer unit, which uses a single, stationary semitransparent mirror like the one shown in figure 40, may be used when more versatility is desired from the projection equipment. While the single front surface mirror is limited to single projector operation, the single semitransparent mirror multiplexer permits immediate switching between two projectors. The more complex multiplexing sys-

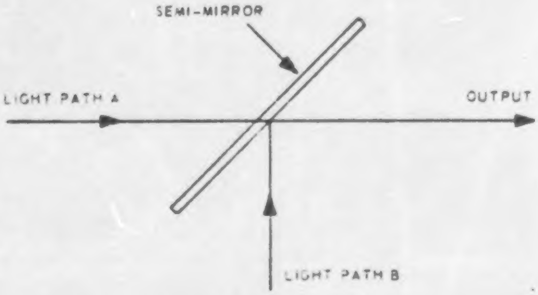

SEMI-MIRROR
LIGHT PATH A
OUTPUT
LIGHT PATH B

Figure 40. Semimirror optical mixing system.

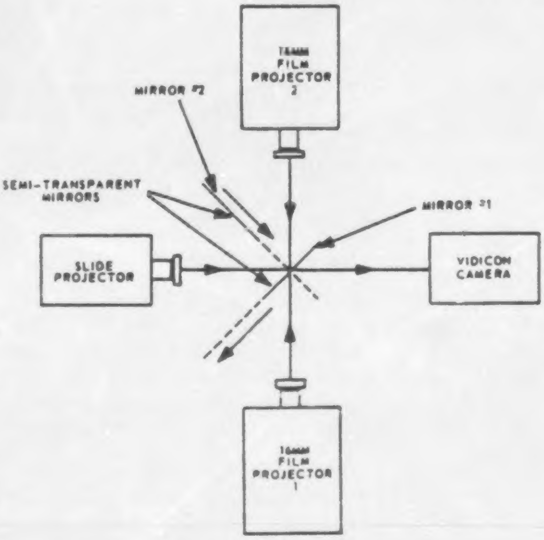

16MM FILM PROJECTOR 2
MIRROR #2
SEMI-TRANSPARENT MIRRORS
MIRROR #1
SLIDE PROJECTOR
VIDICON CAMERA
16MM FILM PROJECTOR 1

Figure 41. Sliding-mirror optical multiplexing system.

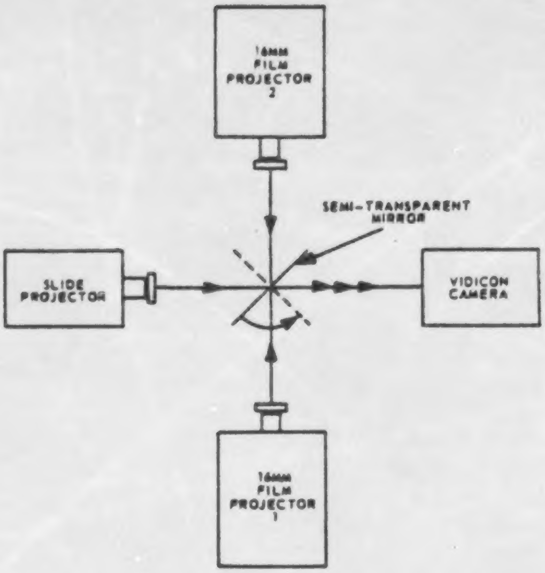


Figure 42. Turnstile-mirror optical multiplexing system.

tems may use sliding mirrors or mirrors that are mounted on turnstile swivels. Complex multiplexers are commonly used because they are much more flexible. Some examples of multiplexers which use sliding and turnstile mirrors are shown in figures 41 and 42. Note that the multiplexer illustrated in figure 41 employs two sliding semitransparent mirrors to direct the projected image onto the camera pickup tube. When mirror 1 is in the center or operating position, it intercepts the projected image from film projector 1 and reflects that image upon the camera pickup tube. Selection of film projector 2 can be made readily by simply moving mirror 1 out of the optical path and mirror 2 into the optical path. This is accomplished when both mirrors are moved in the direction of the arrows. The slide projector can be used at any time because both mirrors are semitransparent.

7-12. An example of a more complex optical mixing system is illustrated in figure 43. Notice that it employes a stationary semitransparent mirror, as well as a movable semitransparent mirror mounted on a turnstile swivel. With this combination of mirrors any one of four sources may be selected. It is also possible to mix inputs A, B, and C or A, B, and D.

7-13. A multiplexer which uses a single semitransparent mirror is illustrated in figure 42. The mirror is mounted on a turnstile swivel which can be turned in increments of 90°. Thus, the mirror is placed alternately in the optical path of projector 1 and projector 2. Since the mirror is again semitransparent, as in the other examples, the slide projector may be used when the mirror is in either position.

7-14. The mirrors cannot be installed in their proper operating positions initially; hence, some mechanical adjustments must be provided. Although these adjustments are made variable over a small range, they are sufficient to permit final alignment of the optical paths.

7-15. Multiplexer complexity is determined by the type, number, and mobility of the mirrors. Since projector design and construction are varied, selection of the types and their positioning are determined entirely by the individual production requirements. Consequently, the flexibility of the entire multiplexing system is determined by multiplexer versatility, varied selection of projectors, and type of camera.

7-16. **Maintenance.** The multiplexer maintenance requirements are much the same as those for other types of television and projection equipment. Periodic cleaning, lubrication, and inspec-

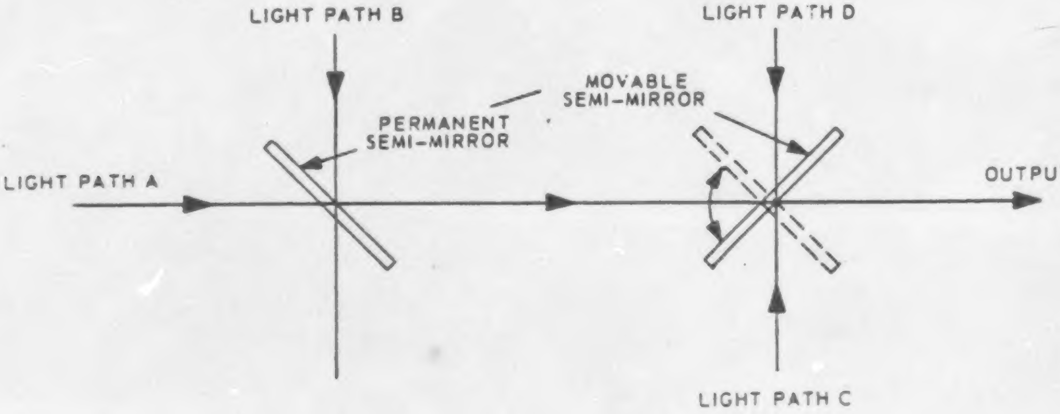


Figure 43. Semimirror optical mixing system.

tion will suffice in most instances. Replacement or repair of broken and damaged components is also of great importance and must be accomplished whether discovered during operation or periodic maintenance.

7-17. Dirty mirrors and lenses decrease the operating efficiency of the multiplexer. Since this is true, all mirrors and lenses must be cleaned regularly. Remember, as in projectors, only an approved solvent and lens cleaning material should be used to clean the glass surfaces of multiplexer components.

7-18. Gear trains and other moving components must be cleaned and lubricated at periodic intervals. Again, only an approved lubricant and solvent or equivalent substitutes should be used on these parts. Periodic inspection of the multiplexer increases its operating efficiency, because all discrepancies discovered and corrected at that time decrease the number of failures during operation.

7-19. Defective components should be repaired at the time they are discovered. If the component is not reparable, it must be replaced with an equivalent part, because the multiplexer must be exact in order not to detract•from the overall operation of the system.

7-20. **Troubleshooting.** Most problems encountered in the multiplexer are mechanical and are relatively easy to locate and correct. The most common problems are dirty, scratched, or broken mirrors and lenses, and misalignment of the mirrors.

7-21. If you discovered for example, that the image being projected from the slide projector (see fig. 41) was out of geometric proportion, while the images projected from the two film projectors were correct, the problem would probably be misalignment of the slide projector. In other words, the slide projector is not operating in the same optical plane as the camera. Since the two film projectors are operating properly, the mirror alignment must be correct.

7-22. In the multiplexer represented by figure 41, we see that the image from film projector 1 is normal, while the image from film projector 2 is washed out. The problem is likely to be a dirty mirror reflecting the image from film projector 2.

CHAPTER 3

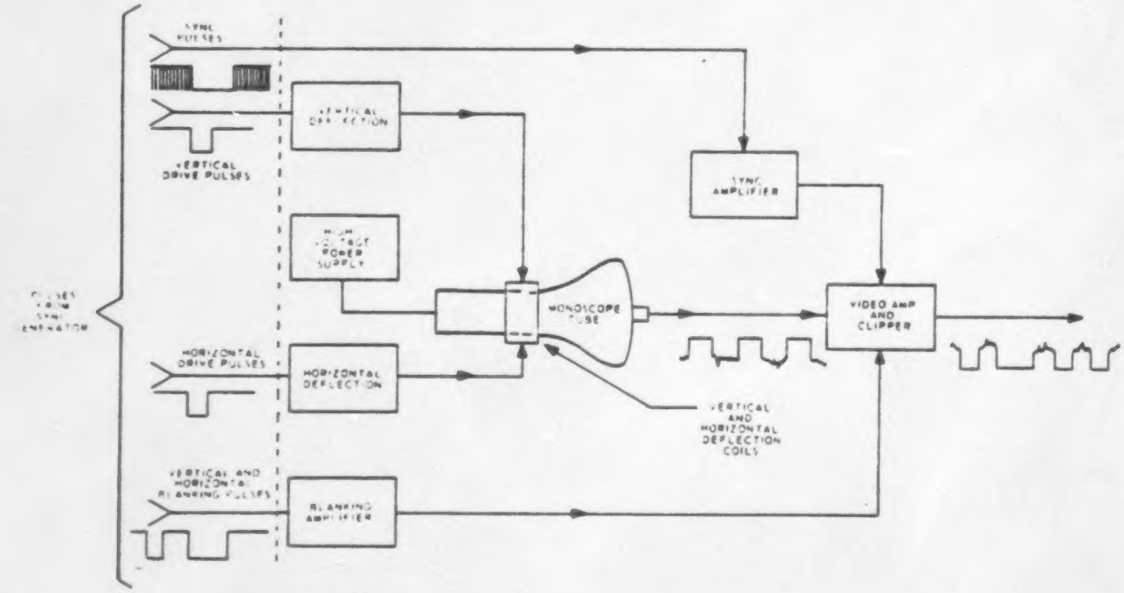
Specialized Test Equipment

ACCEPTABLE television coverage for a given area depends upon the operational and transmission efficiency of the system servicing the area. Television, like all other electronic systems, requires the use of test equipment for proper care and maintenance. In addition, to meet television color, video, and pulse standards, specialized test equipment is required. In this chapter we will discuss some of the specially designed signal generators, signal analyzers, and test patterns required by television. The discussion of this test equipment will include purposes, functions, and general block diagrams, rather than specific models. The chapter also includes a discussion of test patterns and pulses used in making routine performance checks and adjustments and the interpretation of certain test pattern displays and charts applicable to video testing.

8. Monoscope Amplifier

8-1. Since studio and film cameras are so costly television stations find it impractical to use them for test pattern transmission. The monoscope amplifier, often called the monoscope camera, is now used for this purpose since it is much smaller and less costly. The monoscope camera permits the television station to have a single pattern of known quality available for display or test purposes at all times. A block diagram of the monoscope camera is shown in figure 44; our discussion will be concerned primarily with the pecularities of the camera and its use in generating a test pattern.

8-2. **Monoscope Tube.** The monoscope tube contains an aluminum plate which functions much like the mosaic of an iconoscope tube. This



SYNC PULSES
VERTICAL DEFLECTION
VERTICAL DRIVE PULSES
HIGH VOLTAGE POWER SUPPLY
PULSES FROM SYNC GENERATOR
HORIZONTAL DRIVE PULSES
HORIZONTAL DEFLECTION
VERTICAL AND HORIZONTAL BLANKING PULSES
BLANKING AMPLIFIER
SYNC AMPLIFIER
MONOSCOPE TUBE
VIDEO AMP AND CLIPPER
VERTICAL AND HORIZONTAL DEFLECTION COILS

Figure 44. Monoscope camera block diagram.

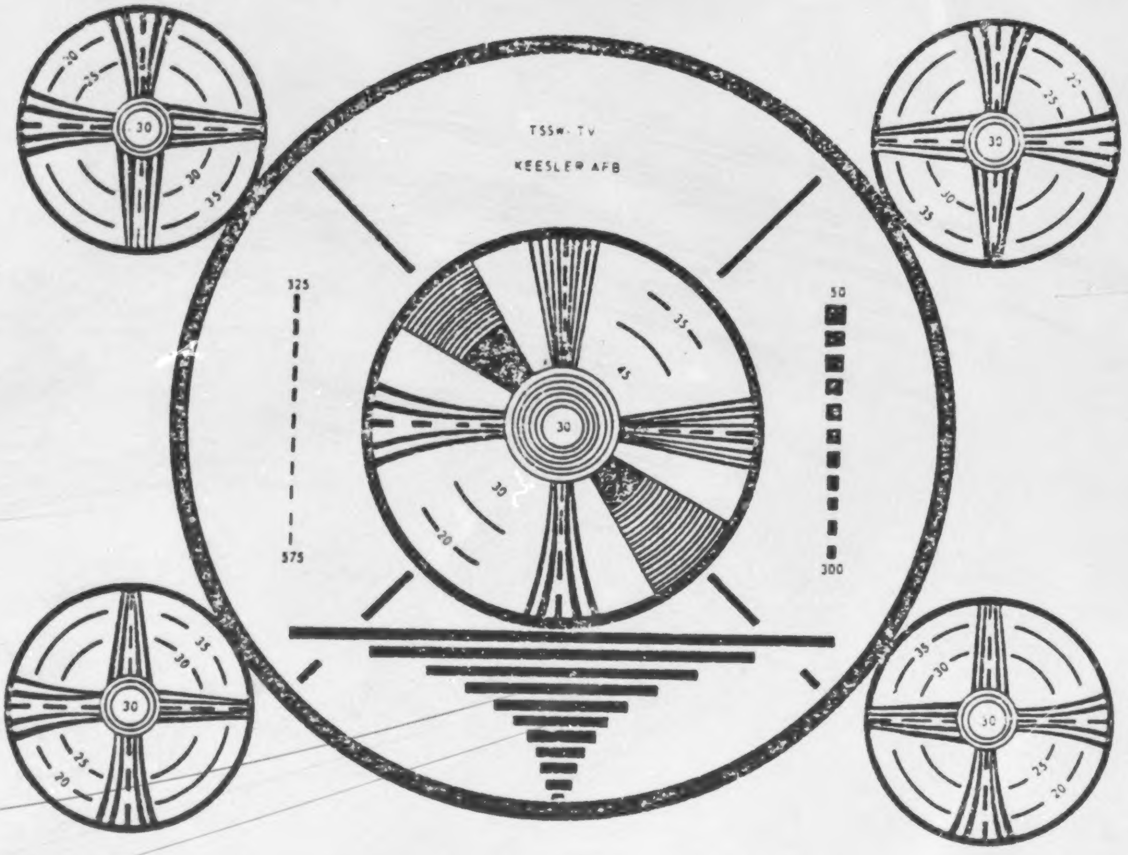


Figure 45. Test pattern, monoscope amplifier.

aluminum plate has a single pattern etched upon it with carbon ink. Since the pattern is etched on the aluminum plate, the tube is limited to a single pattern presentation. The pattern design varies according to the desires of the individual television station; however, its basic purpose remains the same.

8-3. Operation of the monoscope tube is very similar to that of the iconoscope tube. The clear surface of the aluminum plate emits more secondary electrons than the carbonized area. Like the iconoscope, a collector electrode in the monoscope tube collects the secondary electrons. Thus, by systematically scanning the target with an electron beam, a picture signal is produced. Since the clear aluminum surface emits more secondary electrons than the carbonized area, the output picture signal has a negative white component. The standard television transmitted signal, as you already know, has a negative black component. This means that some way of inverting the picture must be incorporated in the monoscope tube or amplifier section. Picture inversion can be accomplished in one of two ways. First, picture inversion can be accomplished by using an odd number of video amplifiers in the monoscope amplifier section to produce a 180° phase shift in the output signal. Second, the pattern can be printed as a negative on the aluminum plate of the monoscope camera tube. In other words, the aluminum plate is coated with carbon ink and the pattern is outlined with clear aluminum. Then the picture signal will contain a negative black component. Either method will produce an output picture signal which is compatible with standard television systems.

8-4. The block diagram of the monoscope camera (fig. 44) illustrates its general circuitry and basic operation. The drive, synchronizing, and blanking pulses are introduced from the external synchronizing generator. The deflection circuits are magnetic; thus, their operation is like that of the image orthicon, vidicon, and iconoscope tube-deflection circuits. Note that the monoscope tube output presentation shows a negative white component. To get the signal inversion shown in the video amplifier output, an odd number of video amplifiers must be used.

8-5. **Pattern Interpretation.** The test pattern presentation from the monoscope tube has many useful purposes. The pattern illustrated in figure 45, for example, may be used to accomplish system quality checks, such as resolution capabilities, low-frequency response, contrast, and deflection linearity. The monoscope camera also provides a modulated signal for transmitter quality and performance tests. When the output of an r-f signal generator is modulated by the output of the monoscope camera, receiver performance can be checked readily against a known standard.

8-6. The pattern presentation illustrated in figure 45 has five sets of wedges, one in each of the four corners and one in the center circle. These wedges provide a reference for adjusting the horizontal and vertical resolution of a television transmitting or receiving facility. The wedge lines are calibrated in lines of resolution—the number of times a system can change from black to white. The center line of each wedge is dashed to mark resolution definition; the number associated with each break in the line, multiplied by 10, defines resolution for that point. The resolution displayed by a given image is determined by estimating the position at which definite separation between the wedge lines is noticeable. The horizontal resolution can be checked by observing the vertical wedges. Since the size of the scanning beam is one of the factors limiting resolution, the resolution definition is an indication of the quality of focus. The corner wedges provide a fixed reference for focusing in the areas where defocusing is most likely to prevail.

8-7. The monoscope camera resolution is limited by the size of the scanning beam and the maximum number of lines available for scanning. Since the monoscope camera tube has an optimum resolution of 500 lines, it cannot effectively reproduce half-tone images. Consequently, an alternate method of producing half tones (gray scale) had to be developed. The diagonal wedges in the center circle of the pattern produce an illusionary standard for measuring gray-scale reproduction. By etching a series of lines at specified intervals, a simulated density range is constructed from light gray to black; the innermost portions of the wedges appear 100 percent black and the outer portions appear 25 percent black, with graduated steps of 75 percent and 50 percent black separating the two extremes. When brightness and contrast controls are properly adjusted, each of the steps in the density range is separate and distinct.

8-8. The horizontal lines beneath the center circle of the test pattern are used to check the low-frequency response of the circuits under test. An excessive phase shift of low frequencies results in a gradual change in shading from top to bottom of the picture, causing bright streamers, or streaks, to follow large dark objects in the scene of a received picture. Thus, the amount of streaking following the end of the horizontal lines in the change from black to white is an indication of the quality of low-frequency response. Good low-frequency response is indicated by little or no streaking.

8-9. The aspect ratio of 4:3 is established when the deflection is adjusted so as to give a true undistorted form to the large circle, since this circle is three-fourths of the pattern width. The diagonal lines indicate an area equal to one-half the picture width. Deflection linearity may be checked by measuring the spacing between the diagonal lines.

9. Video Test Equipment

9-1. In this section we will discuss some of the specialized test equipment associated with television video testing. The discussion will be developed primarily around the grating generator, dot generator, and video sweep marker generator. We will describe their purpose and operation, as well as interpret their output patterns. The section will also include a discussion of the pulse cross display with reference to its usefulness in determining the width and amplitude of the equalizing pulses and both the horizontal and vertical blanking and synchronizing pulses in relation to a general pattern interpretation. We will show some of the standard charts used for television quality checks and briefly discuss the function of each pattern.

9-2. **Grating Generator.** The grating generator provides a convenient means for checking and

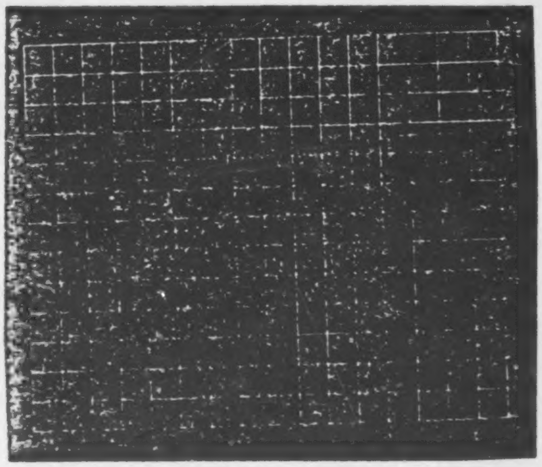


Figure 46. Grating test pattern.

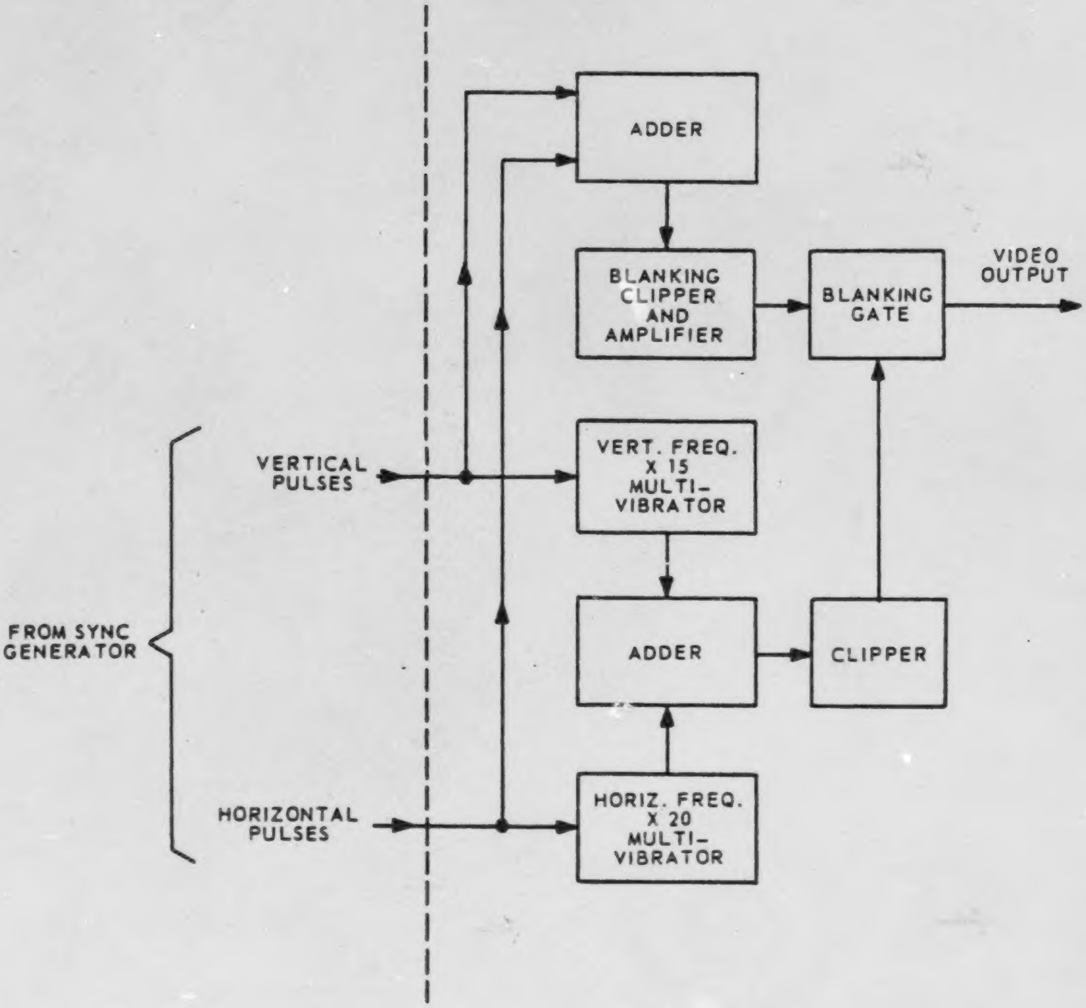

ADDER
BLANKING CLIPPER AND AMPLIFIER
BLANKING GATE
VIDEO OUTPUT
VERTICAL PULSES
VERT. FREQ. X 15 MULTI-VIBRATOR
FROM SYNC GENERATOR
ADDER
CLIPPER
HORIZONTAL PULSES
HORIZ. FREQ. X 20 MULTI-VIBRATOR

Figure 47. Grating generator block diagram.

adjusting the linearity of television deflection circuits. It generates a timing signal synchronized by standard synchronizing pulses, obtained from either the synchronizing generator or the deflection circuits of the receiver under test, and injects this signal into the video circuit being tested. The pattern produced has the appearance of a grating, as illustrated in figure 46.

9-3. The block diagram, figure 47, illustrates the typical grating generator circuitry necessary to produce a satisfactory grating pattern. The desired pattern is produced by inserting the horizontal and vertical synchronizing pulses from either a standard television synchronizing generator or the deflection circuits of a television receiver, as previously stated. The vertical pulses are then multiplied 15 times, while the horizontal pulses are multiplied 20 times. They are vectorially added in the adder circuit and the output is applied to a clipper. The output pattern of the grating generator is determined by the bias point of the clipper circuit. When the bias is adjusted so that either the horizontal or vertical signal extends above the clipping level, the resulting output is a grating pattern. Moreover, the grating signal must be clipped at both ends of the amplitude range so that the lines will not appear blacker than black at their intersecting points.

9-4. To prevent lines from appearing during retrace, the horizontal and vertical retrace pulses are combined, as shown in figure 47. When added, they form a blanking pulse, and this pulse is applied to the blanking gate circuit. An output signal is produced only when the incoming signal is strong enough to override the level of the blanking pulse.

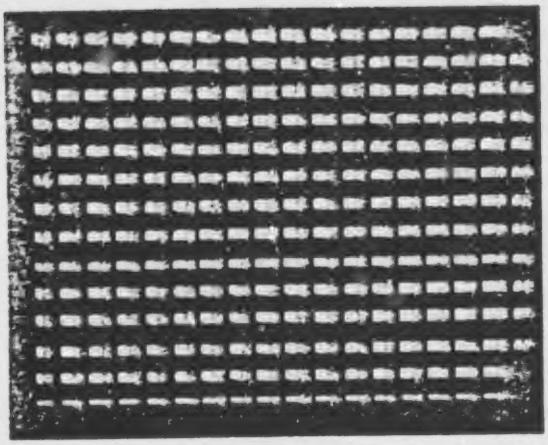


Figure 48. Dot test pattern.

9-5. The grating pattern is comprised of 14 horizontal bars and 17 vertical bars. The bars, being evenly spaced, conform with both the aspect ratio of the television system and the linearity chart, discussed later in this section.

9-6. The grating generator will also produce either horizontal or vertical bars separately. By selecting the output from either the times-15 or times-20 multivibrator and applying it to the signal clipper, the generator output will result in horizontal or vertical bars only.

9-7. By injecting the grating pattern into a receiver or monitor and checking the display uniformity, you can determine descrepancies in the deflection circuits' linearity. The linearity is adjusted properly if the vertical and horizontal bars are both uniformly spaced over the entire viewing area. The grating pattern is also useful when you adjust the linearity of a camera chain. (This will be discussed more fully in the portion concerning chart displays.) Another valuable feature of the grating pattern is apparent when you adjust the convergence of a color receiver or monitor. This feature is discussed further in the section dealing with color testing.

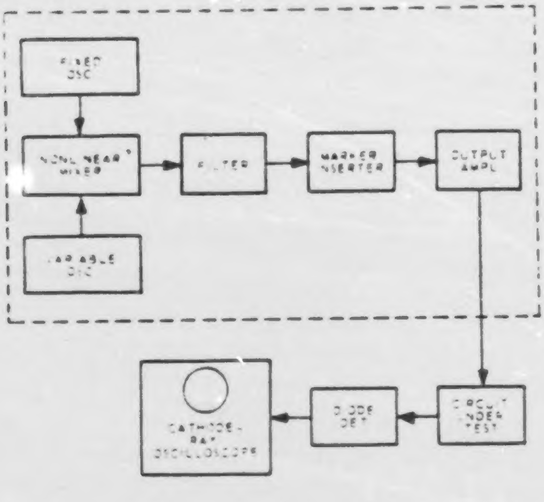


Figure 49. Sweep marker generator block diagram.

9-8. **Dot Generator.** The same generator is often used to generate the dot pattern or the grating pattern. Only the clipper bias point will determine which output is produced. If the signal clipper bias is so adjusted for an output only when the horizontal and vertical pulses are added, a dot pattern will result. The other circuits in the dot generator and their operation are identical to those employed in the grating generator. Thus, figure 47 can also represent a basic block diagram of a dot generator.

9-9. The output pattern from the dot generator is illustrated in figure 48. This pattern is primarily used when adjusting the convergence of a color receiver or monitor and will be discussed in more detail in the next section of this chapter. However, we can now see that a single generator may be used to produce horizontal bars, vertical bars, a grating pattern, or a dot pattern as the need arises.

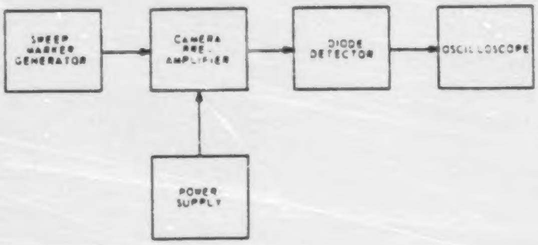


Figure 50. Camera amplifier bandpass check.

9-10. **Sweep Marker Generator.** The video sweep marker generator, shown in figure 49, is a convenient device for checking the frequency response of a given amplifier. In a typical generator, the output of a fixed r-f oscillator, operating at approximately 70 MHz, is heterodyned against a sweep (variable) frequency oscillator. The sweep oscillator is being swept (varied over its frequency range of 69 to 80 MHz) at a 60-Hz rate. The 0- to 10-MHz beat frequency is then applied to the circuit or unit being tested, and the resulting output, after detection, is observed on an oscilloscope. Marker notches are inserted at 1-MHz intervals for frequency calibration of the beat frequency; this is accomplished by an additional oscillator stage in the sweep generator. A more accurate means of calibrating can be obtained with a sweep generator unit that employs a calibrated CW oscilla-

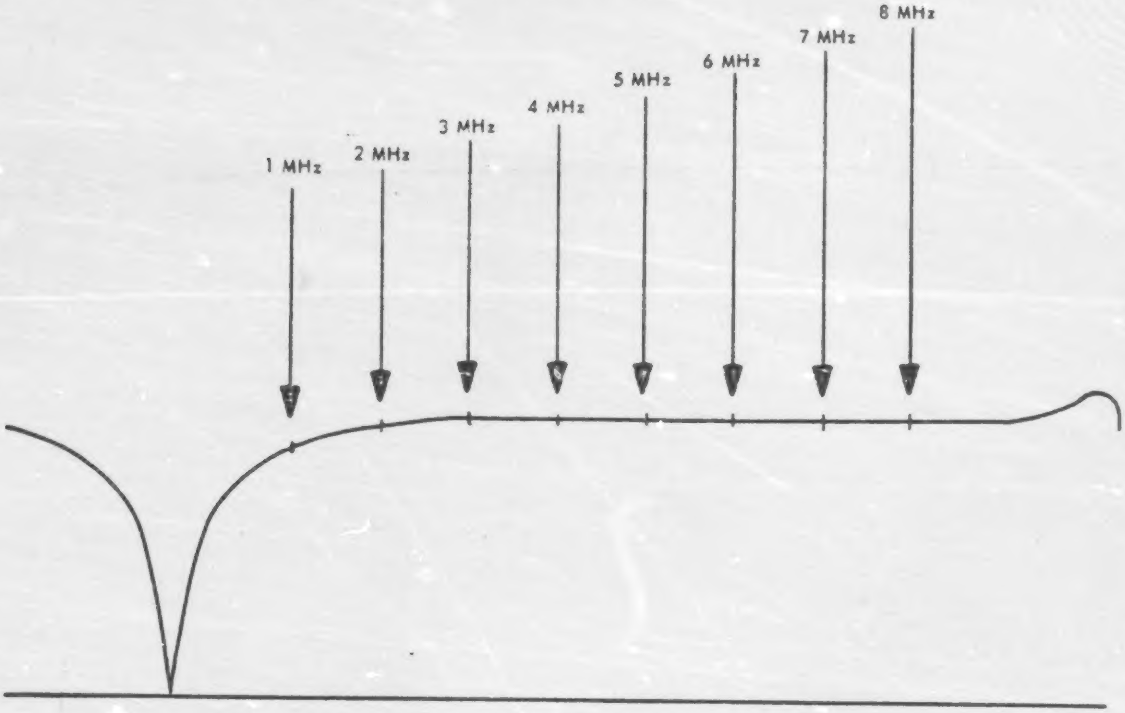


Figure 51. Oscilloscope presentation of camera bandpass.

tor as a marker source. This type of marker source provides either variable or fixed markers over a marker source range of 100 KHz to 10 MHz.

9-11. The most useful function of the sweep marker generator is to test and adjust the bandpass of camera preamplifiers. The equipment layout used to check a camera preamplifier with a sweep marker generator is illustrated in figure 50. Figure 51 shows the output pattern of a properly tuned camera preamplifer as seen on the oscilloscope. Notice the notches inserted in the output pattern. These markers help you observe the range of frequency response of the output pattern from the camera preamplifier. These marks are important since the frequency-response curve must be flat to 8 MHz for adequate bandpass of the television video information.

9-12. **Pulse Cross Display.** The pulse cross display is one of the most important measurements in television and it is used to determine whether the synchronizing generator is producing the proper pulse sequence, width, and amplitude. The pulse cross display, along with its correct interpretation, is a convenient means of conducting operational measurements of the output pulses produced in the synchronizing generator. Other types of more detailed pulse analyses and adjustments may be necessary at periodic intervals: however, these functions will require the use of specialized test equipment. Thus the pulse cross display is more practical for routine operational measurements because this test simply requires the use of a modified video monitor. This monitor is usually available in any television broadcasting station.

9-13. In normal video transmission the horizontal and vertical synchronizng pulses occur at the end of each scanning line and each field, respectively. Thus, the front porch of the horizontal synchronizing pulse occurs at the right edge of the picture, whereas the back porch occurs at the left edge. On the other hand, the vertical blanking interval occurs during vertical retrace. We see then that the information contained in the vertical blanking pulse occurs at the top and bottom of the viewing screen. Since all of the synchronizing and blanking information occurs at the edges of the picture area, its information is hidden by the picture tube mask.

9-14. Though detailed information may be difficult to distinguish, the general shape of the vertical blanking interval can be observed on most standard receivers and monitors by rotating the vertical-hold control until the vertical blanking bar is located in the viewing area. The horizontal synchronizing and blanking pulses, occurring at the end of each scan line, are much more

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difficult to observe; however, with the modifications normally provided, the standard television monitor will eliminate any definition, vertical displacement, or horizontal displacement problems. Thus the pulse cross display can be observed instantly or monitored continually for extended periods of time.

9-15. The individual lines can be seen more readily if the horizontal and vertical scanning process is expanded. As a result, the pulse cross display information is seen in more detail. Expansion of the picture tube sweep circuits will permit the horizontal and vertical synchronizing and blanking information to be placed in the viewing area of the picture tube.

9-16. Interpretation of the pulse cross display is relatively easy when you understand that the individual pulse amplitudes are indicated by light intensity. In the pulse cross display, shown in figure 52, the horizontal dimensions of the light intensities are relative measures of time or pulse widths. Use figure 52 to identify the following pulse group patterns:

A—the horizontal synchronizing pulse duration. (0.075H–0.098H)

B—the horizontal blanking pulse duration. (0.165H–0.18H)

C—the vertical synchronizing pulse interval. (0.42H–0.44H)

D—the vertical blanking interval. (13.1H–21.0H)

E and F—the equalizing pulse intervals.

G—the six dark lines which show vertical synchronizing pulse duration.

I—the equalizing pulse duration. (0.05 horiz sync width)

J—the horizontal blanking and synchronizing pulses that continue to occur at the end of each horizontal video scan line until the beginning of the next vertical blanking interval.

K—the front porch of the horizontal blanking pulse. (0.02H)

L—the back porch of the horizontal blanking pulse. (0.05H)

M—the pulses which occur during the remaining vertical blanking time.

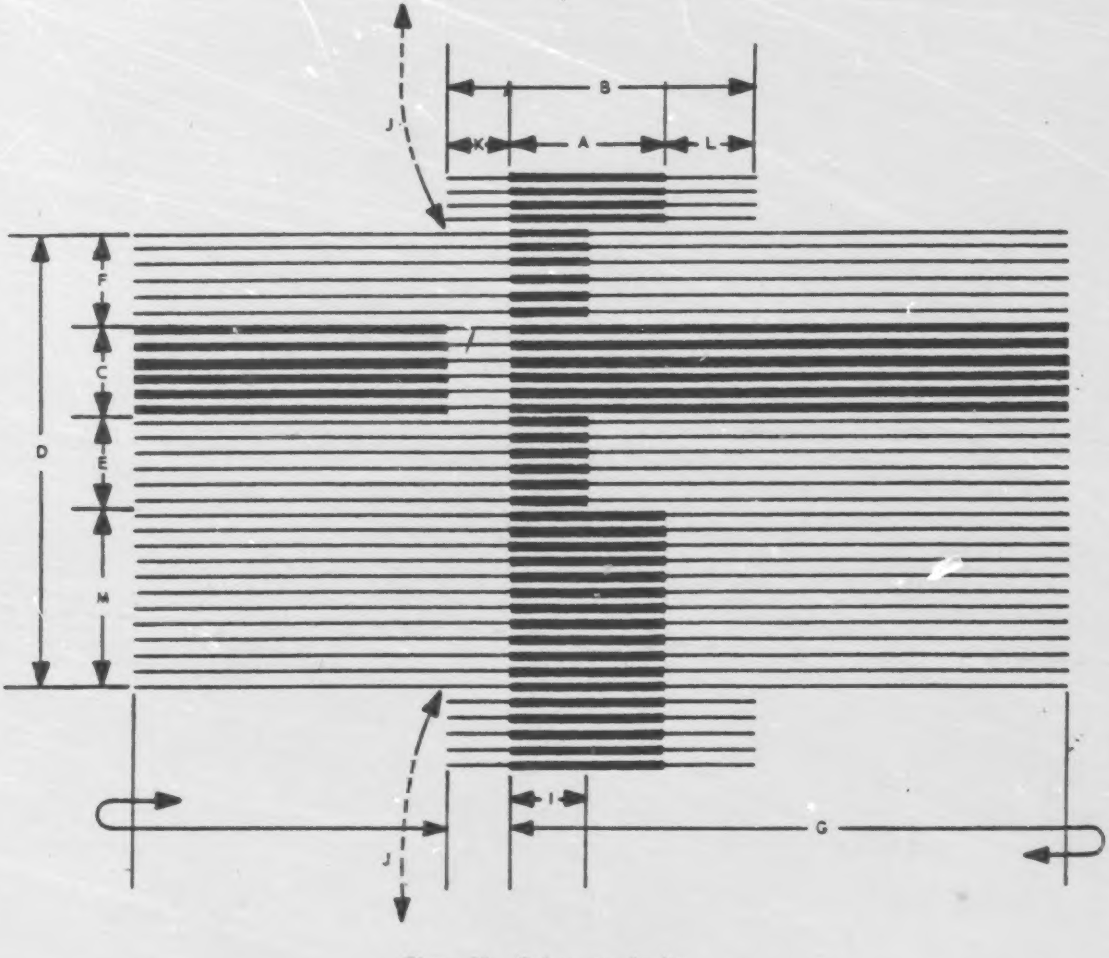

Figure 52. Pulse cross display.

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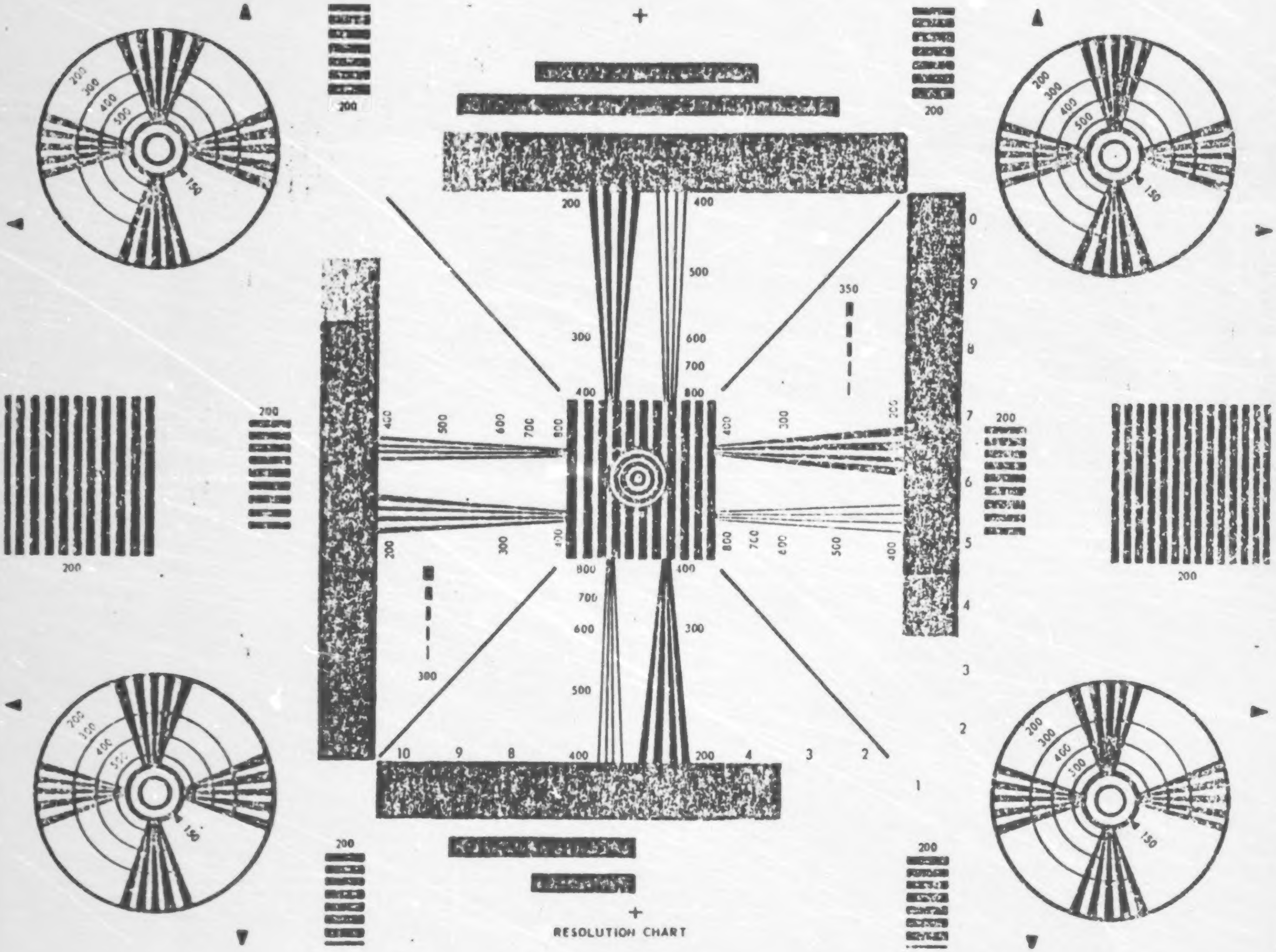

RESOLUTION CHART

Figure 53.

Each pulse width may be compared to its normal duration. You may desire to review portions of Sync Generators, Chapter 3, Volume 1, particularly figure 40, *Table of TV Pulse Standards*. After you have had some experience in using the cross pulse display, you may devise a *ruler* calibrated in normal pulse widths to check the pulse cross display. Of course this ruler would apply only to a particular monitor. You can also use the pulse cross display to check the number of lines in the equalizing and vertical pulses.

9-17. The quality of detail in the reproduced picture is called resolution, or definition, and depends upon the number of basic picture elements that can be reproduced. A picture with good resolution requires as many picture elements as possible. Good resolution of a picture is indicated by sharply defined objects and no blurring or running together of closely spaced lines or points. Horizontal detail and vertical detail must be considered separately in a television picture. The maximum vertical resolution is determined by the number of active scanning lines. The horizontal resolution is determined by the maximum number of changes in voltage that can occur in each line that is scanned. This number of voltage changes depends directly upon the frequency response of the system, the resulting signal bandwidth, the size of the pickup, and the picture tube scanning spots.

9-18. **Test Patterns.** Standard test charts have been developed which permit more comprehensive testing of system performance than the test pattern produced by the monoscope amplifier (discussed in Section 8 of this chapter). The resolution chart shown in figure 53 can be used for making system quality tests for geometric distortion (linearity), aspect ratio, resolution, shading uniformity, frequency response, streaking, interlace, gray-scale reproduction (contrast), brightness, and r-f or other high-frequency interference.

9-19. When making a geometric distortion check, position your camera and focus on the test chart. The resulting picture display will exactly cover the visible portion of the receiver or monitor screen. A picture free from distortion has linear scanning and correct aspect ratio. Check vertical linearity by comparing the spacing between the short horizontal bars at the top, bottom, and center of the picture. If the spacing is equal in each set of horizontal bars, vertical linearity is satisfactory. You can check horizontal sweep linearity by comparing the spacing of vertical bars at each side of the picture and in the center square. If the spacing is equal in each set of vertical bars, horizontal linearity is satisfactory. The circles located in each corner and at the center of the chart are a further check for geometric distortion. Circles that are nonlinear or distorted in shape indicate incorrect adjustment of the vertical, horizontal, or both horizontal and vertical sweep linearity. You can check aspect ratio by measuring the large portion of the picture formed by the four gray-scale bars to determine if it is square. Aspect ratio is correct if the pattern is square and the scanning is linear.

9-20. A resolution check is made only after the set is adjusted for minimum distortion. You measure resolution horizontally and vertically by observing the wedges in the large circle at the center and the small circles at the edges of the picture. The wedge lines are calibrated in lines of resolution in the same manner as those of the test pattern produced by the monoscope amplifier discussed in paragraph 8-9 of this chapter. Resolution of the system under test is numerically defined on the chart at the point where the separation between these lines is no longer discernible. You judge horizontal resolution by observing the vertical wedges at the top and bottom of the circles, but in the case of vertical resolution, you observe the horizontal wedges at the right and left of the circles.

9-21. To check interlace, you observe the diagonal lines in the center square of the picture. Interlace is correct if the lines appear similar to those in figure 53. Jagged diagonal lines indicate partial pairing of the lines. The diagonal lines will not appear jagged if complete line pairing occurs. Under this condition, total line pairing can be determined by the resolution wedges, since vertical resolution cannot exceed 250 lines.

9-22. The quality of gray-scale reproduction is judged by the number of distinguishable steps in each of the four gray scales which form the large square in the center of the picture. The quality of reproduction is related directly to the number of steps that are distinguishable. You check shading uniformity by observing the background of the test pattern presentation. An even gray background indicates satisfactory shading uniformity.

9-23. The dominant white quality of the chart makes it necessary at times to adjust the contrast and brightness controls to obtain a picture pleasing to the eye. The picture should be pleasing to the eye for the average televised program if you adjust the receiver for optimum performance with the chart.

9-24. R-f or other high-frequency interference is sometimes introduced into the video amplifier scanning circuits. R-f interference in the horizontal sweep circuits from the power supply is indicated when the vertical lines in the test pat-

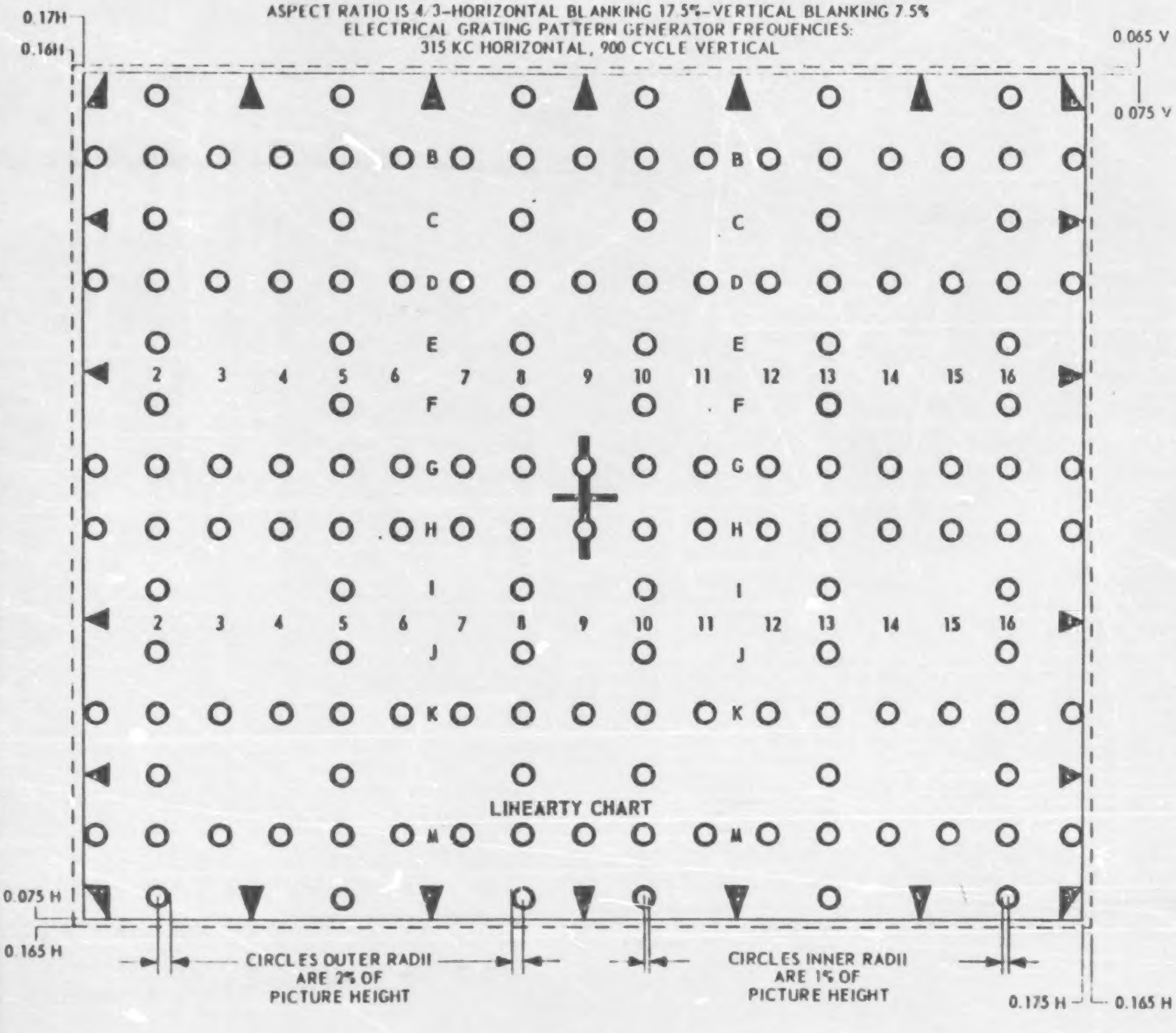

ASPECT RATIO IS 4/3—HORIZONTAL BLANKING 17.5%—VERTICAL BLANKING 7.5%
ELECTRICAL GRATING PATTERN GENERATOR FREQUENCIES:
315 KC HORIZONTAL, 900 CYCLE VERTICAL
0.17H
0.16H
0.065 V
0.075 V
B
C
D
E
F
G
H
I
J
K
M
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
LINEARTY CHART
0.075 H
0.165 H
CIRCLES OUTER RADII ARE 2% OF PICTURE HEIGHT
CIRCLES INNER RADII ARE 1% OF PICTURE HEIGHT
0.175 H
0.165 H

Figure 54.

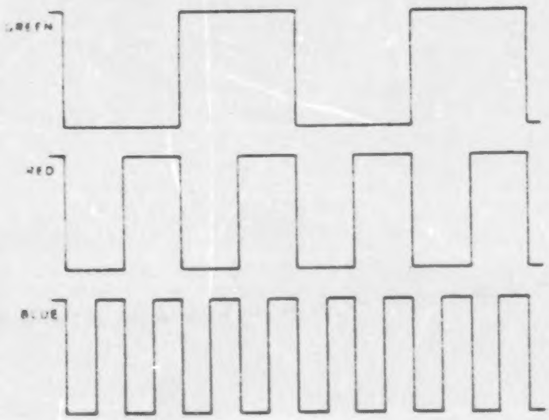


Figure 55. Color-bar generator output waveforms.

tern become modulated and take on a ripple appearance. R-f or other high-frequency interference in the video amplifier is indicated by a moire pattern over the whole picture.

9-25. The standard linearity chart illustrated in figure 54 is used when you make camera linearity adjustments. This chart has an aspect ratio equal to that of the grating pattern (shown in fig. 46). Furthermore, the circles occur at the same positions in the linearity chart that the lines intersect in the grating pattern The two test patterns are superimposed on a monitor screen when you focus the video camera on the linearity chart and simultaneously transmit it and the pattern from a grating generator. A camera with linear scanning produces a picture uniformly distributed on the screen. Therefore, you can adjust the linearity of the camera by adjusting the camera linearity controls so that the circles of the linearity chart coincide with the intersections on the grating pattern (within the acceptable 2 percent tolerance).

10. Color Testing

10-1. Since color television requires more critical standards of operation, some types of specialized test equipment are necessary to maintain these standards. In this section we will discuss the purpose and usefulness of some of the test equipment used to maintain these critical standards. The function of such test equipment as the linearity checker, color-bar generator, color signal analyzer, vectorscope, and grating generator will be discussed. We will also interpret the output patterns produced by this equipment and discuss their oscilloscope presentations.

10-2. **Linearity Checker.** The gain and phase linearity in a color video signal must be maintained at an established level. A composite color signal consists of a luminance component on which is imposed the 3.58-MHz color subcarrier. The subcarrier is modulated in such a manner that the amplitude determines the degree of saturation of the reproduced colors and the phase relationships produce the hue. The typical linearity checker provides a means of measuring the differential gain (system gain variation at different light levels) and differential phase distortion (phase shift at different light levels) of video amplifiers and transmission systems. In general, linearity checkers are signal generators providing a simulated color video signal.

10-3. **Color-Bar Generator.** The color-bar generator is produced in two basic models. The first is a compact, lightweight instrument primarily designed for portability. The second is designed for standard 19-inch rack mounting and is used primarily in television broadcast station operations. In both units the operation is much the same and the desired outputs serve the same basic purpose.

10-4. The color-bar generator serves many useful purposes, such as checking the operation of color television receivers and monitors, adjusting color phase, checking and adjusting color matrix systems, supplying a color reference signal to the signal analyzer, and supplying a color reference signal to the colorplexer.

10-5. The color-bar generator supplies rectangular pulses which are applied to the red, blue, and green input circuits of the colorplexer to form a color-bar test pattern at the colorplexer

Q	WHITE
I	YELLOW
WHITE	CYAN
	GREEN
BLACK	PURPLE
	RED
	BLUE

Figure 56. Location of bars on color-bar pattern.

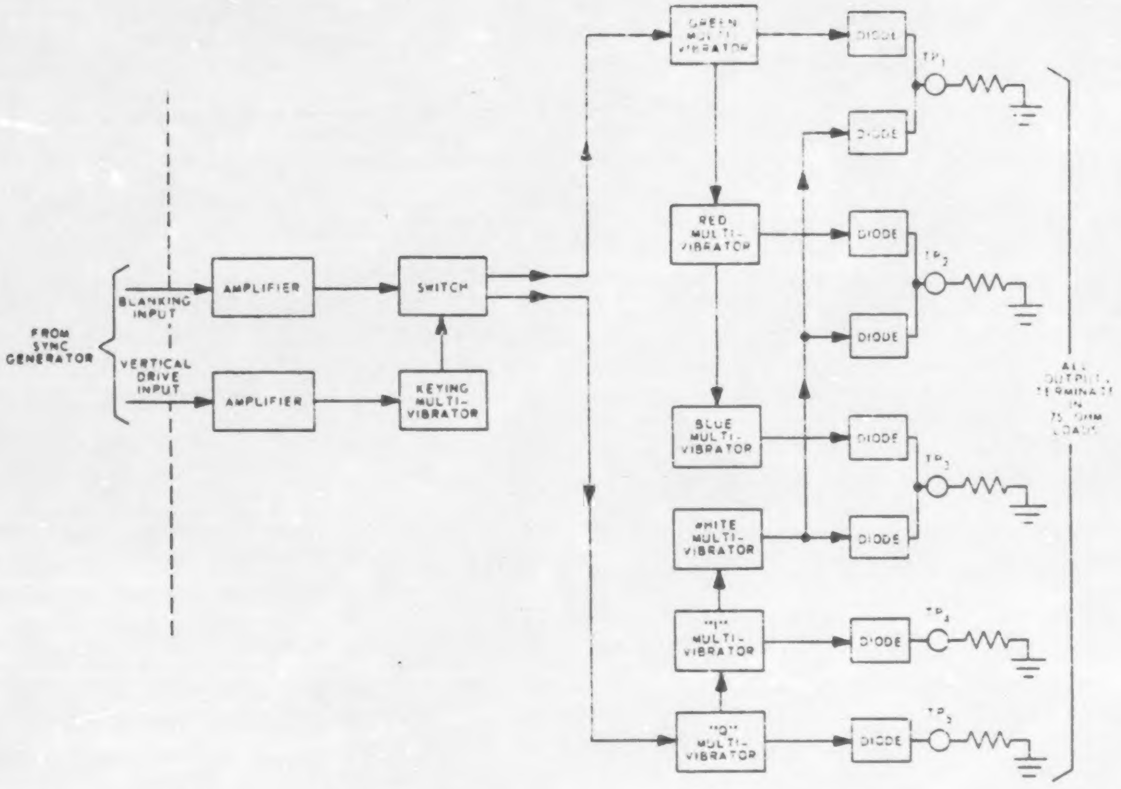

FROM SYNC GENERATOR
BLANKING INPUT
VERTICAL DRIVE INPUT
AMPLIFIER
AMPLIFIER
SWITCH
KEYING MULTI-VIBRATOR
GREEN MULTI-VIBRATOR
RED MULTI-VIBRATOR
BLUE MULTI-VIBRATOR
WHITE MULTI-VIBRATOR
"I" MULTI-VIBRATOR
"Q" MULTI-VIBRATOR
DIODE
DIODE
DIODE
DIODE
DIODE
DIODE
DIODE
DIODE
DIODE
TP1
TP2
TP3
TP4
TP5
ALL OUTPUTS TERMINATE IN 75-OHM LOADS

Figure 57. Color-bar generator block diagram.

output. Provisions are also incorporated to produce a split-field pattern with the standard color bars making up the top portion and the special Q, I, and a white bar making up the bottom portion. Figure 55 illustrates the red, blue, and green pulse shapes and duration. These pulses are produced in the color-bar generator. Figure 56 illustrates how the special Q, I, and white bars are placed in relation to the output color bars.

10-6. Figure 57 shows a basic color-bar generator. Note that the input pulses are received from the synchronizing generator. In the case of a portable color-bar generator, these pulses are received from the deflection circuits of the receiver or monitor under test. The blanking pulse is used to form the wavesshape, amplitude, and duration of the pulses illustrated in figure 55. The keying multivibrator is free-running at 60 Hz. The input vertical drive pulse from the

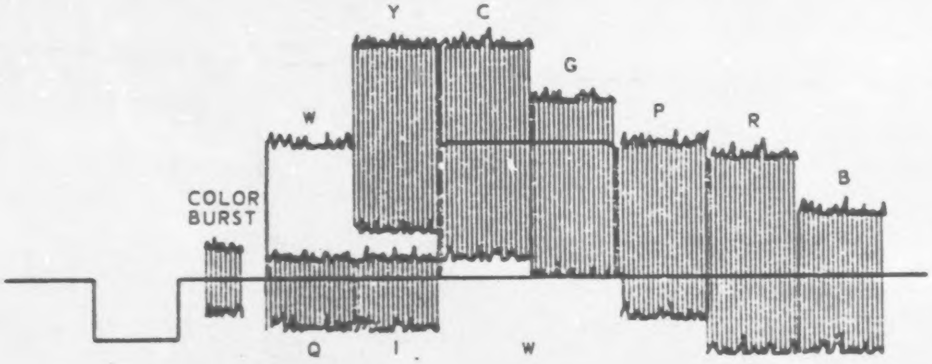


Figure 58. Superimposed colorplexer output signals.

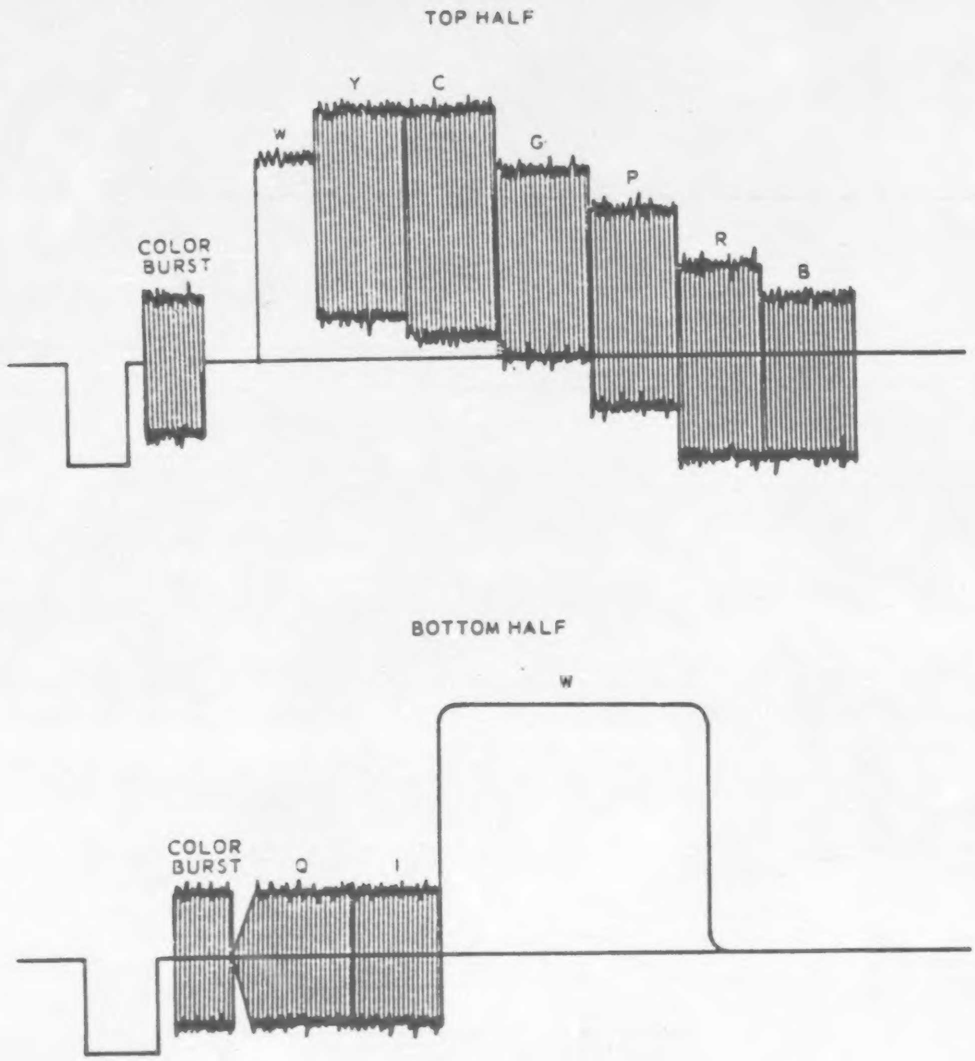


Figure 59. Colorplexer output signals (top half, bottom half).

synchronizing generator keys this multivibrator, producing a split screen pattern. The vector addition of the red, blue, and green pulses generated in the color-bar generator will produce the color bars, as shown at the top of figure 56. The special Q and I signals are derived from the blanking pulse and are produced as separate outputs. The white bar is produced when the I multivibrator output keys the white multivibrator. The output of the white multivibrator is applied to the three primary color outputs in equal amounts. As seen in figure 56 the pulse width of the special Q, I, and white bars are adjusted for one, one, and two bar widths, respectively. When the output signals are coupled through regulating diodes, the output luminance is stabilized. When these signals are applied to the appropriate section of the colorplexer, the output composite signal, with top and bottom halves superimposed (bars at 75 percent level), looks like figure 58. The individual output signals for the upper and lower portions of the picture area appear much like those in figure 59.

10-7. **Color Signal Analyzer.** A color signal analyzer is a test instrument used to study the components of a composite color video and subcarrier signal. (A block diagram of a basic color signal analyzer is illustrated in fig. 60.) When used in conjunction with a color-bar generator and oscilloscope, it permits measurements of the phase relationships between the subcarrier burst

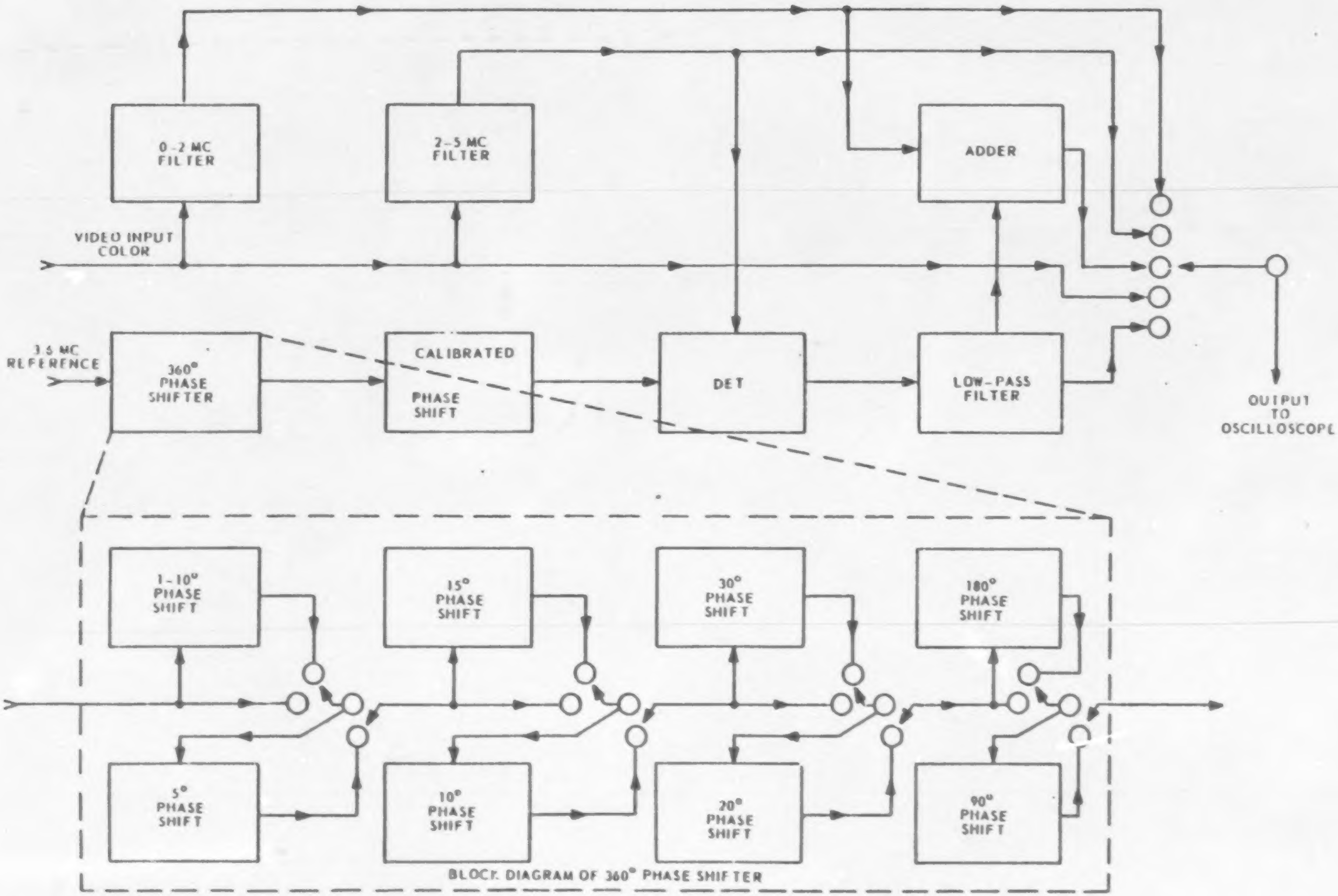

0-2 MC FILTER
2-5 MC FILTER
ADDER
VIDEO INPUT COLOR
3.6 MC REFERENCE
360° PHASE SHIFTER
CALIBRATED PHASE SHIFT
DET
LOW-PASS FILTER
OUTPUT TO OSCILLOSCOPE
1-10° PHASE SHIFT
15° PHASE SHIFT
30° PHASE SHIFT
180° PHASE SHIFT
5° PHASE SHIFT
10° PHASE SHIFT
20° PHASE SHIFT
90° PHASE SHIFT
BLOCK DIAGRAM OF 360° PHASE SHIFTER

Figure 60. Color signal analyzer block diagram.

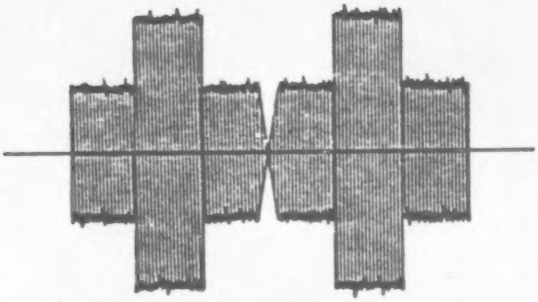


Figure 61. Colorplexer output, modulated I.

reference and the various components of a composite color signal. It may be used also with a linearity checker to make differential phase measurements.

10-8. Notice in figure 60 that the 360° phase shifter consists of several fixed and variable phase-shifting circuits; thus, the input signal can be shifted a full 360°, in increments of 1°. This is possible because the individual phase shifters total 360° and one 10° shifter is adjustable in increments of 1°. The capability of being able to shift the incoming signal 360° is necessary because phasing of the individual color component signals is critical if an acceptable composite color signal is to be achieved.

10-9. When the colorplexer is operated in the color-bar mode, some representative oscilloscope patterns as they appear at the input of the color signal analyzer are modulated I (fig. 61) and modulated Q (fig. 62), respectively. When the output signals are demodulated, they can be phased properly with minimum problems. In addition, the phase relationship between any of the input signals and the subcarrier or between the individual input I, Q, red, blue, and green signals can also be checked. Using the color subcarrier as a reference, you see that the signals can be phase shifted in the 360° phase-shifting network. The I signal must be 90° out of phase with the color subcarrier. To do this, insert the modulated I color signal component (fig. 61) into the color signal analyzer. In the color signal analyzer the I signal is demodulated to simplify the phase adjustments. Next, select a 90° phase shift and adjust the I phase control on the colorplexer until all the pulses rest on the reference line. After removing the inserted phase shift, phase the color signal component properly in relation to the color subcarrier. Employ the same adjustment procedure when dealing with the Q signal component. However, since it is only 33° out of phase with the color subcarrier, it requires only a 33° phase shift when making the necessary tests and adjustments.

10-10. The phase relationships between individual input pulses can be checked if you first place one signal on the reference line (color subcarrier) and then place the second input signal on the reference line. You can determine the amount of phase shift between the two input signals by finding the difference between the two phase insertions which were necessary to place the two signals on the reference line. In other words, if the first pulse signal was 90° out of phase with the reference line and the

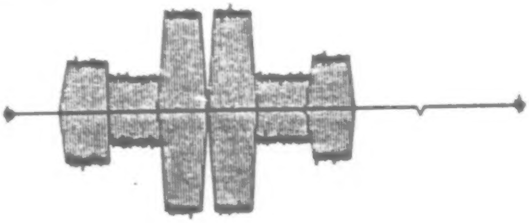


Figure 62. Colorplexer output, modulated Q.

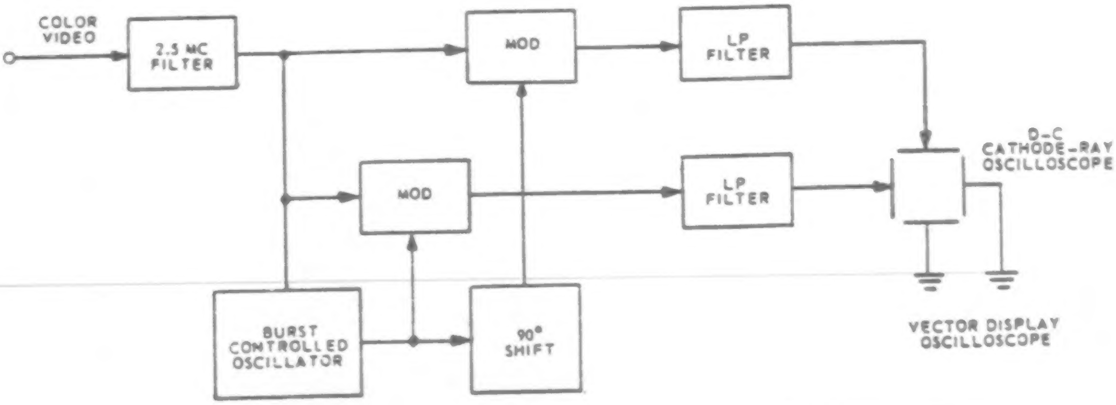

COLOR VIDEO
2.5 MC FILTER
MOD
LP FILTER
MOD
LP FILTER
D-C CATHODE-RAY OSCILLOSCOPE
BURST CONTROLLED OSCILLATOR
90° SHIFT
VECTOR DISPLAY OSCILLOSCOPE

Figure 63. Block diagram of a typical vector display oscilloscope.

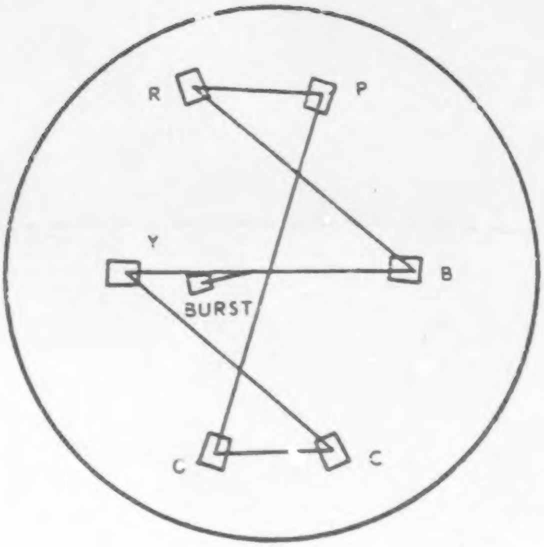


Figure 64. Typical vector display oscilloscope pattern.

second pulse signal 33° out of phase, the difference would be 57°. The first pulse signal would then be 57° out of phase with the second pulse signal. You can now see that the color signal analyzer has many useful purposes for insuring the proper operation of the color-bar generator and colorplexer.

10-11. **Vectorscope.** One of the newer test equipment items developed for close inspection of amplitudes and phases of subcarrier signals is the vector display oscilloscope, commonly called the vectorscope. A block diagram of a typical vector display oscilloscope is shown in figure 63. Generally, this equipment uses a pair of quadrature demodulators. The demodulator outputs are applied to the X and Y plates of a d-c oscilloscope. Most designs incorporate a burst-controlled oscillator to generate a reference subcarrier from the synchronizing burst of the signal under test.

10-12. When used with color-bar signals, the vectorscope produces a pattern of lines and dots which indicate the vectors corresponding to the various colors. The pattern appears as bright dots linked by relatively faint lines. As illustrated in figure 64, boxes may be drawn on the oscilloscope face to indicate phase and amplitude tolerances.

10-13. By comparing our discussion of the vectorscope and the color signal analyzer, we find that the two pieces of equipment perform many of the same functions. Furthermore, we know that both have their advantages and disadvantages. Future planning seems to indicate more varied uses for the vectorscope, including facilities for monitoring the camera output signals at the camera.

10-14. **Grating Generator.** The purpose and outstanding features of the grating generator, as it applies to black and white television, were developed earlier in this chapter. Now we will examine its operation and functions as they pertain to color television testing.

10-15. The cross-hatch pattern generated by the grating generator is extremely useful when making adjustments in the convergence of a color receiver or monitor. When viewing the picture area of the receiver, with the grating pattern applied, look for proper alignment of the vertical and horizontal bars. The convergence is properly adjusted if the bars are placed over one another and no color fringing is apparent.

10-16. **Dot Generator.** The dot pattern produced by the dot generator is also very useful for testing and adjusting color receiver and monitor convergence. As with the grating generator, place the dots one upon the other; if no color fringing is apparent, the convergence is properly adjusted. Though either the grating or dot pattern may be used for convergence adjustments, the dot pattern is usually preferred since it shows which direction the correction must be applied.

VHF Equipment

THIS CHAPTER concerns transmitters, antennas, and receivers. However, since very-high-frequency (VHF) equipment is the lowest in frequency used by TV, the VHF equipment is discussed prior to ultra-high-frequency (UHF) equipment. In this chapter you will study the VHF equipment necessary to create, amplify, modulate, and radiate a carrier frequency. Also discussed is the equipment necessary to pick up, amplify, and reproduce both visual and aural signals.

11. VHF Transmitters

11-1. VHF transmitter principles employ many of the basic transmitter circuits. Normally these circuits will consist of an oscillator, fre-

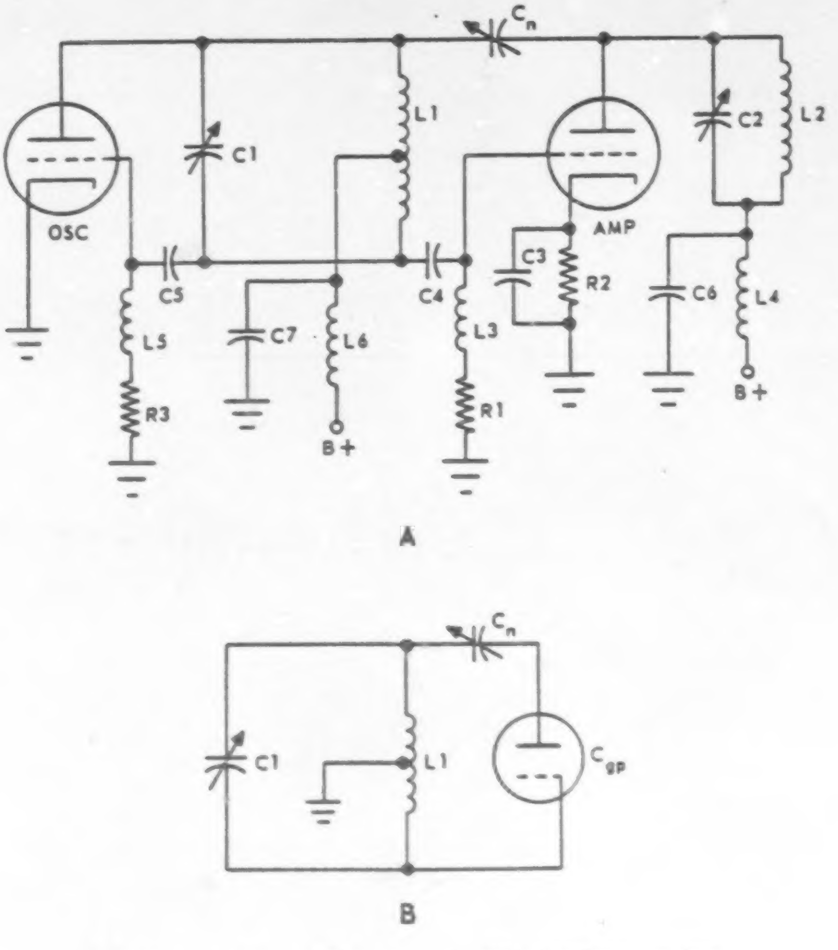


Figure 65. Master oscillator power amplifier (MOPA) transmitter.

quency multiplier, modulator, and r-f amplifier. The first part of our discussion will be devoted to basic transmitters.

11-2. **Transmitter Principles.** You will recall that the basic transmitter consists of an oscillator connected directly to an antenna. Because of certain limitations, this circuit is unsatisfactory as a means of transmitting communications. There are two main drawbacks in connecting the oscillator directly to the antenna. First, the power output is limited because there are no stages of r-f amplification between the oscillator and the antenna. The second limitation of a variable frequency oscillator transmitter is its lack of frequency stability. The frequency of an electron-tube oscillator is, of course, controlled by the inductance and capacitance of its frequency-determining circuits. Coupling a loading device, such as an antenna, to the output of the oscillator has a great effect on its frequency stability. The load impedance of the oscillator is the reflected impedance of the antenna. This reflected impedance contains both resistive and reactive components. The resistive component lowers the Q of the tank circuit and the reactive component alters the resonant frequency.

11-3. Another problem, frequency stability, arises in the use of VHF and UHF transmitters. Although the frequency of an oscillator can be stabilized by use of a crystal, transmitters must operate at much higher frequencies than a crystal can be cut to operate. The crystal oscillator, therefore, must be followed by frequency multipliers to provide the desired output frequency.

11-4. The oscillator determines the frequency stability of a transmitter. An unstable oscillator will cause an unstable signal to be radiated by the antenna. A master oscillator power amplifier (MOPA) circuit can be used to overcome the instability of the antenna-coupled oscilllator. (An example of a MOPA circuit is shown in fig. 65.) The output of the series-fed Hartley oscillator is coupled through C4 to the power amplifier (PA) stage. The oscillator stage is isolated from the antenna by the PA and will not be affected by changes in antenna-to-ground capacitance. Changes in the plate impedance of the PA will not be reflected into its grid circuit and back to the oscillator. The signal applied to the grid of the PA from the oscillator will cause the plate tank of the PA to oscillate at the frequency of the oscillator. The MOPA circuit normally is not used with crystal oscillators, but generally is used in conjunction with one of the common variable frequency types such as Colpitts or Hartley oscillators. Selection of the type of oscillator will depend on the purpose for which the transmitter is intended. If the frequency must be variable yet stable, an electron-coupled oscillator may be selected.

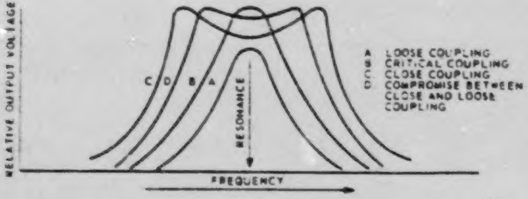
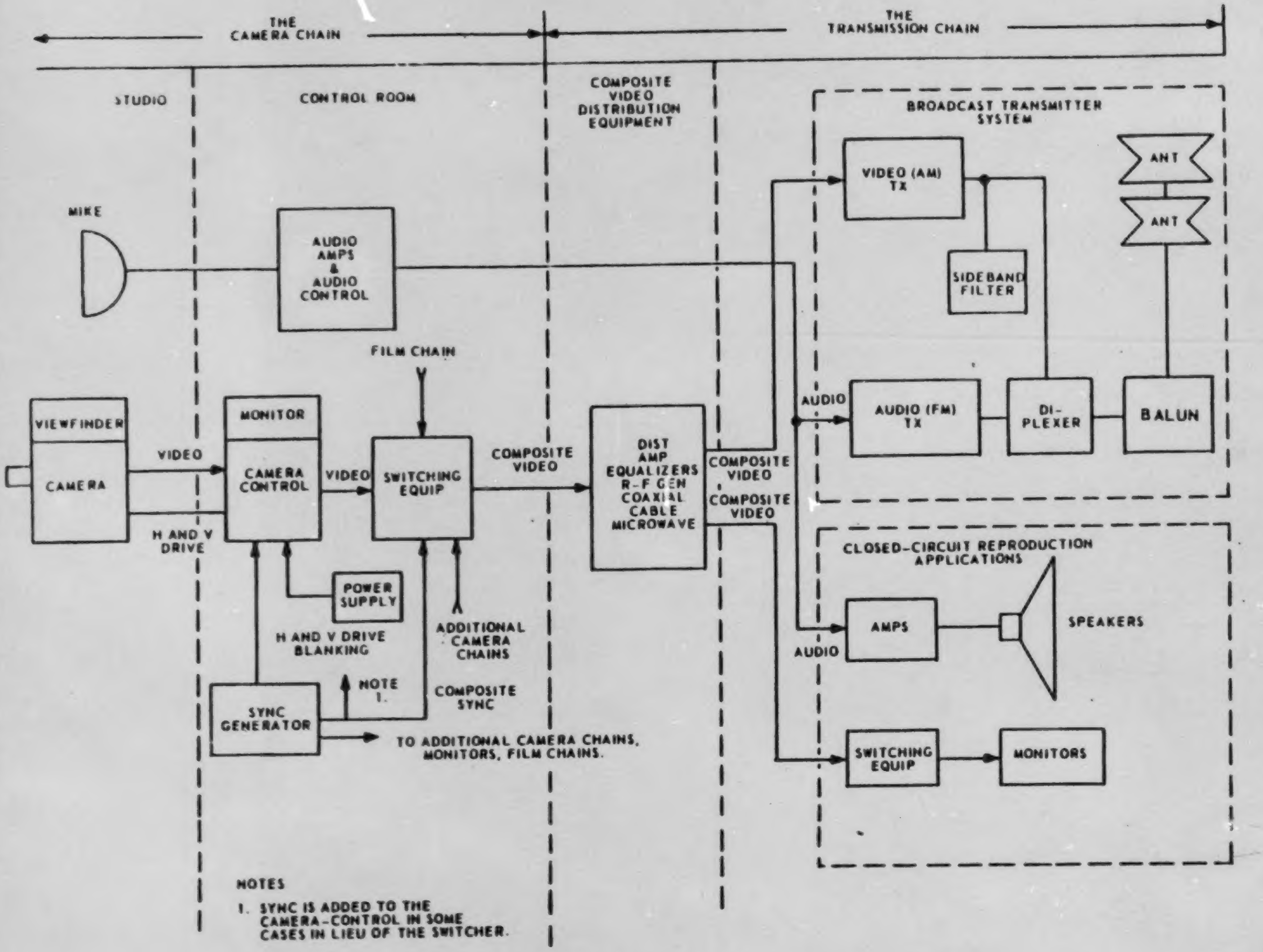


Figure 66. Coupling response curves.

11-5. Stages are coupled by one of three methods—capacitive, inductive, and link. In figure 65, C4 is a coupling capacitor and provides a low-impedance path for the r-f energy from the oscillator tank to the grid of the power amplifier. It also acts as a blocking capacitor by preventing the high d-c potential on the oscillator plate from reaching the grid of the amplifier tube. Capacitive coupling is simple and is used frequently in low power amplifier stages. However, it has some disadvantages that limit its use in the higher frequency ranges.

11-6. Inductive coupling is used extensively in transmitters. This type of coupling is possible because magnetic lines of force set up by the current in one coil will induce a voltage into another coil. The extent to which the lines of force of the energized coil (primary) cut the other coil (secondary) is measured in henrys. This is called mutual inductance (M). In figure 66, notice the various response curves resulting from the different degrees of coupling. In the curves shown, the input voltage applied to the primary is held constant in amplitude while its frequency is varied. If each circuit is independently tuned and the coupling kept loose, the overall frequency response assumes the form shown by curve A. The double-humped curve shown by curve C results from a coefficient of coupling that is greater than critical coupling. As shown in curve D, it is possible to work out a compromise between very loose and very close coupling and arrive at a uniform response to a small band of frequencies.

11-7. Link coupling is actually a special form of inductive coupling and is commonly used in transmitters. The link consists of a low-impedance line terminating in a coil at each end. This coupling is made at a point of low potential, called the nodal point. The nodal point occurs at the ground end of the tank in single-ended stages and at the center of the coil in balanced circuits such as the push-pull amplifier. By operating at a point of low voltage, link coupling


THE CAMERA CHAIN
THE TRANSMISSION CHAIN
STUDIO
CONTROL ROOM
COMPOSITE VIDEO DISTRIBUTION EQUIPMENT
BROADCAST TRANSMITTER SYSTEM
MIKE
AUDIO AMPS & AUDIO CONTROL
VIDEO (AM) TX
SIDEBAND FILTER
ANT
ANT
FILM CHAIN
VIEWFINDER
CAMERA
VIDEO
H AND V DRIVE
MONITOR
CAMERA CONTROL
VIDEO
SWITCHING EQUIP
COMPOSITE VIDEO
DIST AMP EQUALIZERS R-F GEN COAXIAL CABLE MICROWAVE
COMPOSITE VIDEO
COMPOSITE VIDEO
AUDIO
AUDIO (FM) TX
DI-PLEXER
BALUN
POWER SUPPLY
H AND V DRIVE BLANKING
ADDITIONAL CAMERA CHAINS
CLOSED-CIRCUIT REPRODUCTION APPLICATIONS
AMPS
SPEAKERS
AUDIO
SYNC GENERATOR
NOTE 1.
COMPOSITE SYNC
TO ADDITIONAL CAMERA CHAINS, MONITORS, FILM CHAINS.
SWITCHING EQUIP
MONITORS

NOTES

1. SYNC IS ADDED TO THE CAMERA-CONTROL IN SOME CASES IN LIEU OF THE SWITCHER.

Figure 67. Basic elements—broadcast and closed-circuit television transmission.

can eliminate harmonics which might otherwise be transferred by capacitive coupling.

11-8. **Transmitter Signals.** The transmission chain of a television system, as shown in figure 67, includes equipment for transmitting the television signal through space or coaxial cable. Commerical broadcast TV information is, of course, transmitted by radiated signal through space to the reproducing devices—the TV receivers. Other TV applications, explained earlier, utilize coaxial line to transmit TV information between the camera chain and the reproducing devices. The type of auxiliary equipment used for video distribution between the camera chain and either the transmitter (broadcast) or video display units (closed-circuit applications) depends on the location and the distance to be covered. The video and sound in the broadcast system must be transmitted by electromagnetic radiation to the TV receivers. In closed circuit systems, however, raw video may be used for direct production of the televised scene on the screens of specific TV monitors.

11-9. The audio chain (fig. 67) is parallel to but separated from the video chain. In closed-circuit application the audio system will frequently be composed of stock audio components such as the microphones, amplifiers, and speakers found in an ordinary public address system. For a television broadcast studio, however, most audio components will be chosen because of their adaptability to FM operation.

11-10. The *visual transmitter* takes the video signal from the camera chain and passes it through the amplification and modulation process to produce an amplitude-modulated r-f output. Also included are the equipment components necessary to form the proper bandpass characteristics to meet FCC standards. The *aural transmitter* takes the original audio signals and frequency-modulates and amplifies the r-f signal to obtain the final modulated output. We can see from this description and figure 67 that there are two separate transmitters.

11-11. The television transmitter operating band refers to the frequencies at which the transmitter may be operated. A low-band VHF transmitter may be tuned and operated in channels 2 to 6, or at frequencies of 54 to 88 MHz. A high-band VHF transmitter may be used to operate in channels 7 to 13, or at frequencies of 174 to 216 MHz. Some types of VHF transmitters are designed to operate in any one of the channels 2 through 13. A UHF transmitter (discussed in the next chapter) operates in channels 14 to 83, or at frequencies of 470 to 890 MHz.

11-12. *Visual transmitter.* The functional stages of a visual transmitter are indicated in figure 68. The composite video signal from the camera chain reaches the transmitter through the various ways already mentioned. The video modulator and d-c restorer function to modulate the r-f signal in accordance with the incoming video information and to maintain the blanking and sync peak levels at fixed values. The r-f stages of the transmitter usually contain a crystal-controlled oscillator, followed by frequency-multiplier stages to attain the desired operating frequency. The r-f signal strength is then increased by amplifier stages to a level desired for modulation. Modulation of the r-f carrier takes place at a driver or power amplifier stage. Linear power

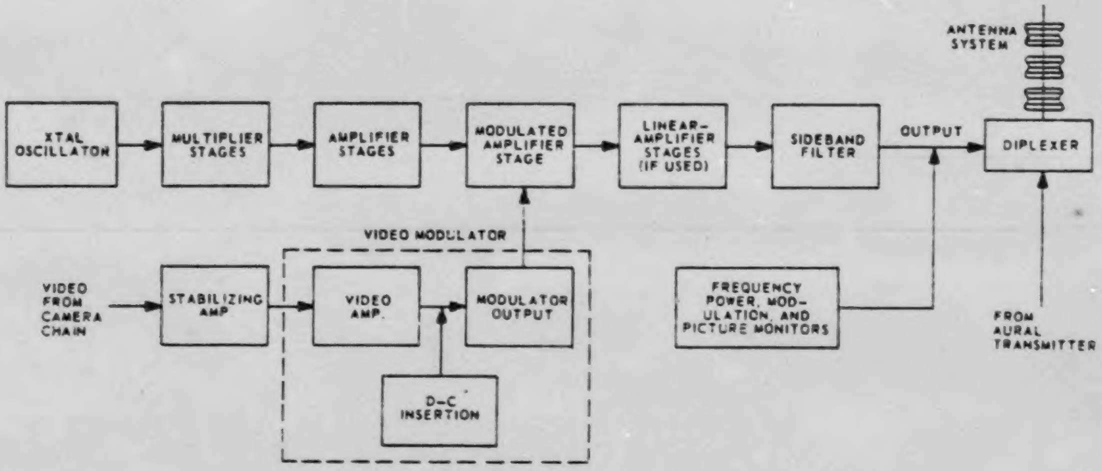


Figure 68. Block diagram—visual transmitter functional stages.

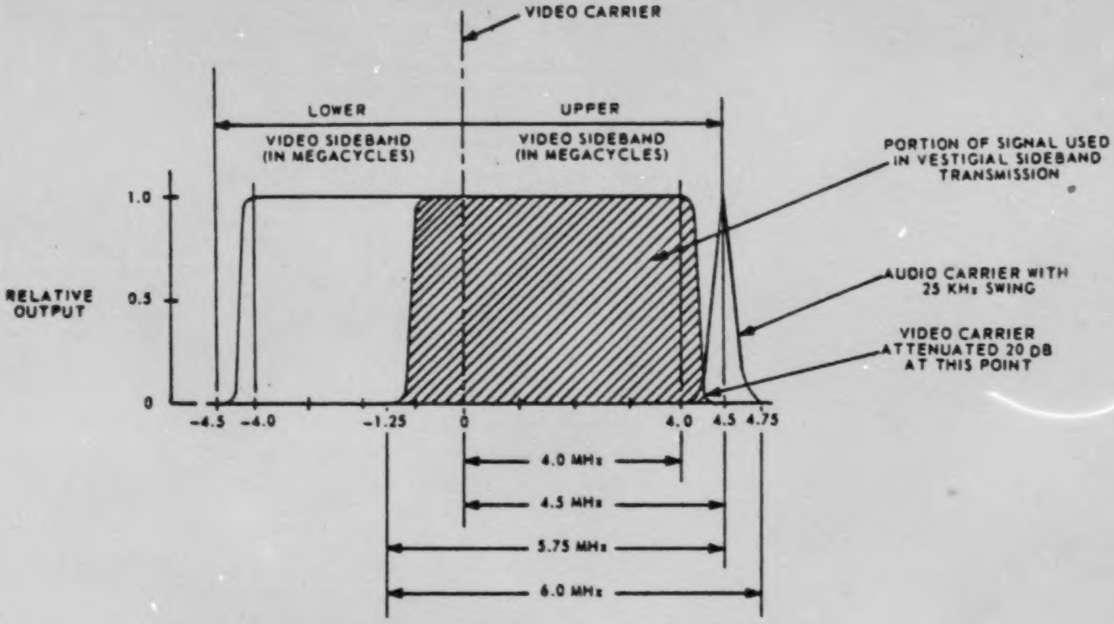


Figure 69. Distribution of signals on a standard television channel.

amplifier stages, including the output power stage of the transmitter, are used following the modulated stage.

11-13. The visual signal must be maintained within certain tolerances. The visual carrier frequency of a station must be held stable within a tolerance of ±1000 Hz. The aural carrier must be maintained at 4.5 MHz ±1000 Hz above the visual carrier frequency. Television channels of 6 MHz are necessary to transmit both the audio and picture information. You can appreciate the space occupied by a TV channel by comparing the AM broadcast band with a single TV channel. The 106 10-KHz channels in the AM band extend from 540 to 1600 KHz. All 106 radio stations occupy much less frequency space than a single TV station.

11-14. Higher bands of frequencies are allocated to TV stations than those used for standard radio broadcasting so that there may be a reasonable number of channels available. The overall allocations for TV channels are split into two bands in the VHF range (as already indicated) and one more band in the UHF range. In all bands of VHF and UHF, every channel is 6 MHz wide. The VHF channels by number and frequency are allocated as follows (the UHF band will be listed in the next chapter):

Channel Number	*Frequency Range in MHz*
2	54–60
3	60–66
4	66–72
5	76–82
6	82–88
7	174–180
8	180–186
9	186–192
10	192–198
11	198–204
12	204–210
13	210–216

11-15. The frequency gaps between the TV bands are used for other purposes. One TV broadcasting channel can be used concurrently by many TV broadcasting stations, provided the stations are separated by at least 150 to 225 miles. This separation is necessary in order to minimize the interference between these stations. They are known as co-channel stations. Stations that use channels adjacent to one another in frequency are termed "adjacent-channel stations." To minimize interference between them, adjacent-channel stations are not assigned to the same city but are separated by at least 50 to 75 miles or more. However, channels consecutive in number but not adjacent in frequencies, such as channels 4 and 5 or channels 6 and 7, can be assigned in one local area. The standard TV channel (shown in fig. 69) consists of both the picture and sound carriers plus their corresponding sidebands. Notice that the picture carrier and its signal sidebands occupy approximately 5.75 MHz of the 6-MHz bandwidth. The sound carrier, however, which is frequency-modulated, with a maximum deviation of ±25 KHz, occupies the remainder of the bandwidth. (Fig. 69 is scaled to show a channel width of 6 MHz.) To calculate the distribution of signals for any specific channel, consider the −1.25 point as representing the lower frequency extreme in MHz and the 4.75 point the upper frequency extreme in MHz. To find the picture carrier frequency of channel 5, add the low sideband of the picture carrier −1.25 MHz to 76 MHz. This will result in a picture carrier frequency for channel 5 of 77.25 MHz. To find the sound carrier frequency, add the upper video sideband of the picture carrier 4.50 MHz to 77.25 MHz. The sound carrier frequency for channel 5 will be 81.75 MHz.

11-16. You can see in figure 69 that the high-frequency sideband of the picture carrier is 4.5 MHz wide, while the low-frequency sideband is only 1.25 MHz wide. This unsymmetrical distribution permits transmission of a picture with better definition while using only a 6-MHz channel. This method is called vestigial sideband transmission. Using this method will provide a great savings in the TV frequency allocations in the frequency spectrum. The picture carrier frequency is located at the 0-MHz point in the channel. The high-frequency sideband of the picture carrier is flat to the 4.0-MHz point and then drops off to almost zero at 4.5 MHz. The low-frequency sideband (−1.25 to 0 MHz) of the picture carrier is flat for 0.75 MHz and then drops off to almost zero in the remaining 0.5 MHz. These 0.5-MHz dropoff areas are the video guard bands whose purpose is to prevent interaction between the video and audio signals.

11-17. *Vestigial sideband filter.* There are various methods of attenuating the unwanted portion of the lower sideband. The transmitter using low-level modulation may provide some attenuation of the lower sideband by tuning the broadband linear r-f stages toward the desired upper sideband. An advantage of this mode of operation for sideband suppression is the ability of being able to adjust the transmitter for any channel within its tunable range without using the sideband filter. In most cases a sideband filter is incorporated in the system to furnish absolute sideband attenuation.

11-18. Absolute sideband suppression is accomplished by placing a sideband filter between the output of the final stage and the antenna load

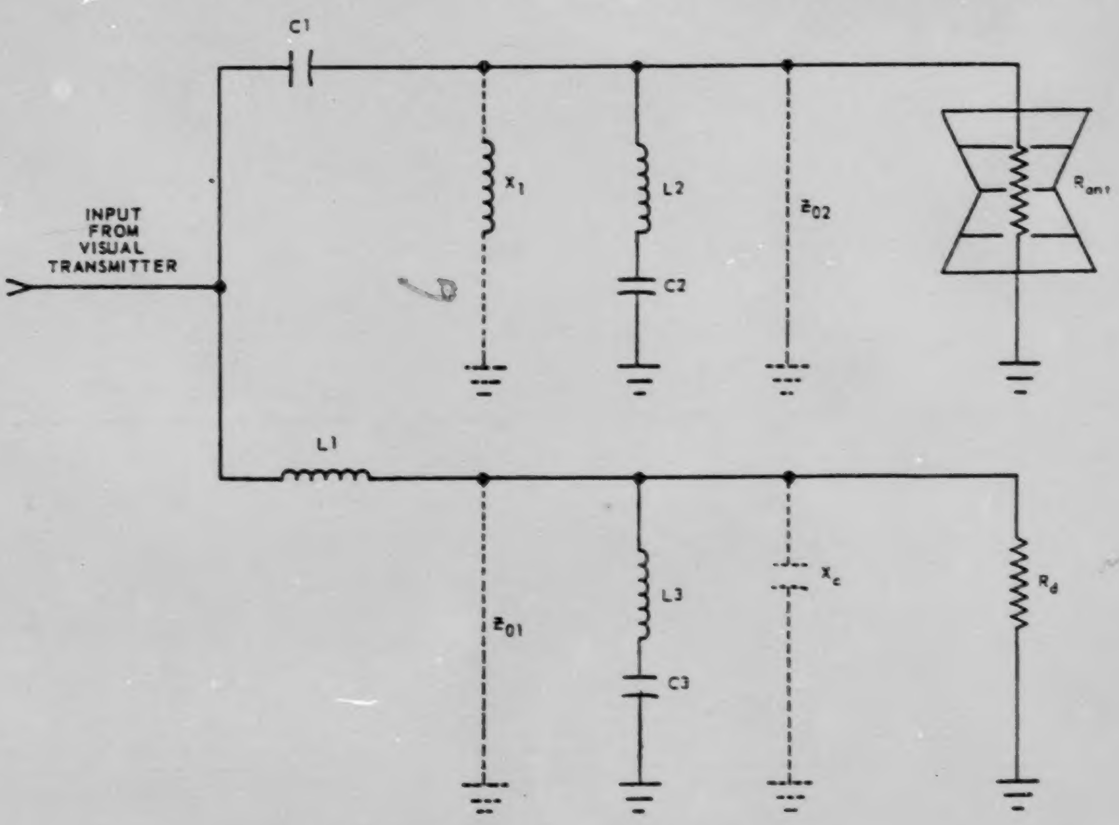


Figure 70. Vestigial sideband filter.

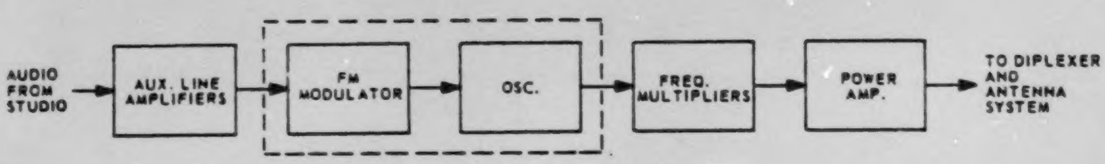


Figure 71. Block diagram—aural transmitter functional stages.

system. All final-stage modulated systems must use a filter, since stagger-tuning is not possible as used in the case of prefinal-stage modulated systems. The entire sideband suppression in final-stage systems is accomplished by filtering, with the power being dissipated in the form of heat. A disadvantage of this system is that a separate filter must be designed and used for each operating channel.

11-19. In order that the power-handling capability may be made less severe, the filter unit may be placed between the modulated stage and a class B linear amplifier stage. The physical size of the sideband filter is determined by its frequency of operation and power-handling capability. Sideband filters used for UHF transmission are made considerably smaller than those for VHF.

11-20. A theoretical schematic of a vestigial sideband filter system is shown in figure 70. The sideband filter is made up of suitable lengths of coaxial line which are used to simulate the inductive and capacitive elements as required. The filter output must have the characteristic output impedance equal to the antenna resistance R_{ant}. R_{ant} is the antenna radiation resistance, and R_d is a dissipating resistor which removes the energy of the unwanted frequencies. The tuned circuits, formed by coaxial lines, determine the frequencies to be passed to and radiated by the antenna and the unwanted frequencies to be passed to and dissipated by R_d.

11-21. The series-resonant circuit L3-C3 is tuned to a frequency slightly lower than the carrier frequency. At this frequency and higher, the impedance of L3-C3 will be zero (Z_{c1}); this effectively moves ground to the bottom of L1 and short-circuits R_d. At the same time, the circuit components L2-C2 appear as an inductive reactance X1. The effective filter circuit for this frequency will be a pi type filter as shown by L1-C1 and X1 of figure 70. All the available power for the video signal at this frequency and higher (depending on the designed bandpass) will be fed to the antenna represented by R_{ant}. The effective circuit represents a high-pass filter.

11-22. The series-resonant circuit L2-C2 is resonant to the desired cutoff frequency (that point of the lower sideband frequencies at which attenuation will start to take place). At this frequency and lower, the circuit impedance of L2-C2 is zero (Z_{c2}), resulting in an effective short circuiting of the antenna (R_{ant}). At the same time, L3-C3 will appear as a capacitive reactance, X_c. The effective filter circuit at this frequency and lower will be a pi type filter as shown by X_c, L1, and C1 of figure 70. In this case all the energy will be dissipated by the resistor R_d. This effective circuit represents a low-pass filter.

11-23. As a result of the foregoing action, the high frequencies of the operating band are passed more easily to the antenna and the low frequencies to the dissipating resistor, to form the frequency band-pass response of the signal required by FCC. The resistor R_d is designed to handle sufficient power dissipation. Even so, the greatest part of the total energy to be transmitted is found at the carrier frequency and near the carrier frequencies in the sidebands. This indicates that the resistor receives only a small amount of the total power.

11-24. Because the frequency response of a filter begins to rise again at frequencies below the desired cutoff point, the vestigial sideband filters actually used are designed more elaborately than the one shown in figure 70. Added sections of coaxil line provide more absolute attenuation of the unwanted lower sideband frequencies. If a vestigial sideband filter is inserted after the final r-f stage (as shown in fig. 68), the output of the filter will feed a diplexer. If the filter is used at an earlier stage, the output of the final r-f stage will feed the diplexer. The diplexer is usually employed to permit the visual and aural transmitters to feed into a common antenna system.

11-25. *Aural transmitter.* Figure 71 represents a block diagram of the functional stages of the FM aural TV transmitter. The audio signal arriving from the studio is usually reamplified to produce operating levels. Amplification is accomplished with a line amplifier inserted at the transmitter end of the studio-to-transmitter line. A compression amplifier is often used after the audio signal has been amplified to prevent overmodulation of the transmitter. The compression amplifier also permits settings of average modulation levels close to the allowable limits.

11-26. The audio frequency is applied to the FM modulator unit where frequency-modulation takes place and the center frequency of the aural signal is initiated and controlled. The FM signal is controlled either directly, by a crystal followed by multiplier stages, or through the comparison of two frequencies derived from a master oscillator and a crystal oscillator. In the latter method, a difference of frequency produces a corrected voltage which is applied back to the master oscillator to provide frequency stability. The frequency control of the initial signal must be highly stable in order to provide the proper frequency difference (4.5 MHz) between the visual and aural carrier signals for application of the intercarrier principle.

11-27. The number of frequency multiplier stages depends on the initial frequency produced in the modulator-oscillator section and the operating band for which the transmitter is designed. The general principles found in TV aural transmission are almost identical with these used in FM radio broadcasting. The main difference is that FM radio is designed with a center frequency deviation of 75 KHz, whereas the deviation in TV is only 25 KHz. Monitors are used to record the carrier frequency (center frequency) and modulation deviation readings continuously. A loudspeaker is provided in most cases for aural monitoring of the signal, and provisions are made for noise and distortion measurements. The tolerance for the aural center frequency under monochrome standards is set at ±1000 Hz. Distortion must be held to current FCC standards. With ±25 KHz being defined as 100 percent modulation, measurements are made at 100, 50, and 25 percent. Maximum distortion ranges from 2.5 to 3.5 percent, depending on the modulation frequency. The power output of the aural transmitter output must meet minimum and maximum FCC standards. These standards are expressed as a relationship between the aural and visual transmitter outputs. For example, the standard may require that the aural output be from 80 to 110 percent of the visual output. The signal from the aural transmitter is passed on to the diplexer through coaxial cable, which connects to an antenna system common to the visual transmitter.

11-28. *The diplexer.* A diplexer unit is employed by TV systems using one antenna for the transmission of both the aural and visual signals. Besides connecting the two separate transmitter output signals to a common antenna system, the diplexer also prevents intercoupling between the two signals. A tee-diplexer used in VHF band transmission is shown in figure 72.B, along with a schematic of the equivalent circuits fed by the two signals (fig. 72,A).

11-29. As you can see, the diplexer schematic shows the use of the familiar Wheatstone bridge. This principle achieves the desired isolation between the two transmitter inputs. The arrangement also permits the symmetrical feeding of the two transmitter outputs to the TV transmitting antenna system. The output of the visual transmitter is applied across one pair of bridge points

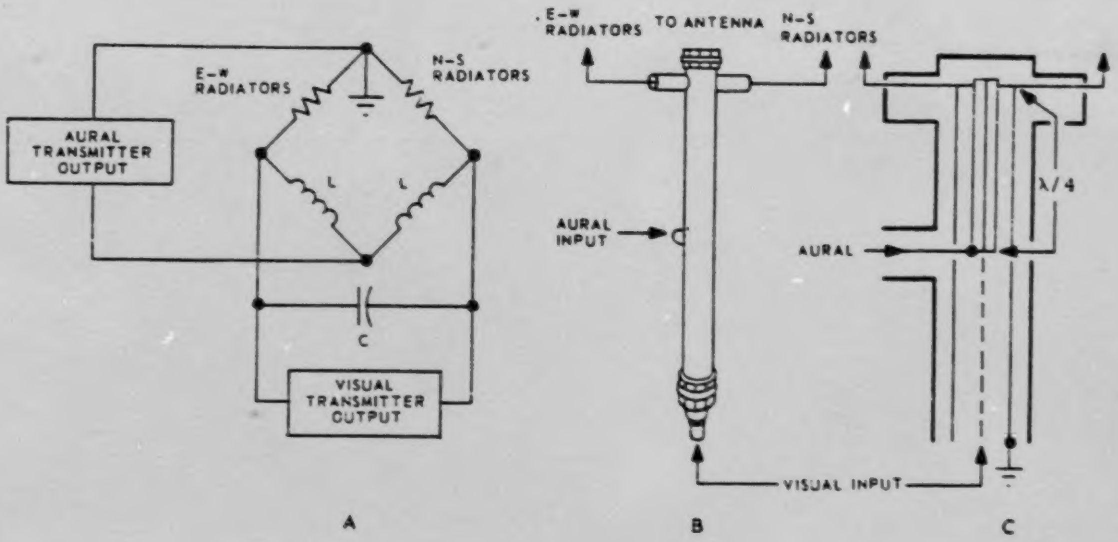


Figure 72. Diplexer and equivalent circuit.

while the aural transmitter is applied across the other pair. The two antenna outputs constitute adjoining arms of the bridge while split sleeves form the bridge arms opposite the antennas. If the arms of the bridge are in perfect balance, the energy applied to one pair of bridge points will not appear at the other pair. Crosstalk, therefore, will be eliminated by carefully balancing the bridge arms. The diplexer must be designed and built for specific operating frequencies. For UHF frequency application, of course, the diplexer is much smaller in size than the types used in the VHF bands. Notice in figure 72.A. that the antenna load presented to the aural transmitter is unbalanced to ground (single-ended), whereas the visual transmitter output load is balanced to ground (double-ended). The output of the visual transmitter is normally single-ended (coaxial line). To convert the visual output to match the double-ended load of the bridge diplexer, a device known as a balun is used. (The theory of baluns will be discussed in the next section.) The construction of the bridge diplexer is based on the split balun (fig. 72.C), in which the outer conductor of a coaxial line is split for a quarter-wavelength (inductor L in fig. 72.A).

11-30. **Transmission Polarity.** In the United States negative transmission is standard for the TV picture carrier. Negative transmission is a carrier which is modulated so an increase in picture brightness results in a decrease in signal amplitude. In a negative transmission the tips of the synchronizing pulses represent maximum carrier level. The highlights in the picture correspond to the maximum carrier amplitude. An advantage of negative transmission is that it makes use of the nonlinear transmitter modulation characteristic sometimes encountered. Because of the rectangular shape of the synchronizing pulses, any compression or saturation taking place during the modulation process only reduces the amplitude of the pulses; otherwise, their shape is not materially affected. It is also possible to compensate for compression by preemphasizing the synchronizing pulses before modulation. In this way a correct ratio of picture-to-synchronizing pulse amplitudes is maintained. In a positive transmission system the highlights of the picture correspond to the maximum carrier; however, any nonlinear region of the modulation characteristic cannot be used without compression of the white portion of the picture signal. A large portion of the low end of the modulation curve (which is usually completely linear) is used up by the synchronizing pulses.

11-31. Negative transmission has the advantage that noise peaks will produce black spots or streaks rather than white in the reproduced picture. For this reason black "noise" is generally less objectionable than white "noise," especially if the amplitude of the white noise is great enough to produce blooming of the picture-tube scanning beam. The picture tube, therefore, serves as a partial noise limiter in a negative transmission system because the interference cannot become any blacker than black.

11-32. Normally, negative transmission systems will have an average power rating of the transmitter. This is less than that for a positive transmission system because the duty cycle of the synchronizing pulses is small as compared to the average picture waveform. This means that the average transmitter power requirements are less when the synchronizing pulses (negative transmission), rather than the picture waveform (positive transmission), determine the maximum peak power needs. Negative transmission also offers advantages in TV receiver design with respect to automatic gain control and the intercarrier sound system.

11-33. **General Maintenance.** Finding troubles that develop in a transmitter is relatively quick and simple if you follow a few definite rules. There is a general procedure that can be followed in troubleshooting which, with a few specific rules, can be made to apply to any particular transmitter. In most transmitters practically all troubles can be isolated to a stage by using meter indications. The following normal indications listed are those where the meter is located in the cathode circuit.

11-34. *Oscillator.* The meter will indicate total oscillator tube current. When the plate circuit is tuned, the meter reading will "dip" if the oscillator is functioning normally.

11-35. *Doubler.* The meter indicates doubler tube current and the reading will dip when you are tuning the doubler plate circuit if all the preceding stages are operating normally. Care must be taken to obtain the lowest dip in this position or the stage will be tuned to the wrong harmonic.

11-36. *Tripler.* The meter indicates total tripler tube current; when the plate circuit is tuned, the meter reading will dip if the tripler is receiving drive from the preceding stage and is working normally. Again, care must be taken to obtain the lowest dip or the stage will be tuned to the wrong harmonic.

11-37. *Power amplifier.* The meter indicates power amplifier tube current and will dip when tuning the plate circuit. This will be true only if all the preceding stages are operating normally and the grid circuit is properly tuned.

11-38. If a transmitter is designed to use grid readings in addition to cathode readings, remember that a grid reading will be for *maximum* current rather than a dip. The meter actually indicates the grid drive of a stage. This drive or reading should increase as the plate circuit of the *previous* stage is tuned to resonance.

11-39. When troubleshooting a transmitter, start with the oscillator and continue until you reach the stage giving an abnormal meter reading or no meter reading. This should, of course, be the defective stage. Most maintenance will consist of cleaning filters, cavities, and other components. The other major maintenance items will consist of tube and fuse replacements. The problems to be solved will be easy if you will "read" the symptoms and reason them out.

11-40. **Color Transmitters.** Many of the transmitters used by commercial companies were designed before color requirements were completely standardized. As a result, because of initial investments, modifications have been developed to adapt these transmitters to color operation. We can conclude from this statement that TV transmitters are fundamentally the same for monochrome and color. The main factor to be considered, relative to color transmission, is the reduced tolerance limits. Some specific problems are the filters and clampers of the various transmitter circuits which tend to distort the burst signals and the "whiter-than-white" overshoots.

11-41. The new transmitters being designed and used are able to meet the FCC standards in the sections dealing with permissible subcarrier amplitude and phase errors. There are certain auxiliary units designed to be used with a color TV transmitter. These units include stabilizing amplifiers, phase and amplitude equalizers, time delay precompensation sections, and linearity correctors. Parts of these units are passive networks, while others are units with circuits of solid state or tube design. The vestigial sideband filter for color transmission must be adequate to keep the burst signal radiation to the −60-db level specified by the FCC.

12. VHF Antennas

12-1. The antenna system is the link between an individual transmitting station and its receiving station or stations. Regardless of the form of the TV antenna, its main purpose is to radiate or receive signal-bearing r-f energy. An antenna system can be considered to include the antenna itself, the feed line, and any coupling devices used for transferring power to the line and from the line to the antenna. In this section we will consider the characteristics of transmission lines at various frequencies, the propagation and radiation characteristics at various frequencies, the requirements of VHF television antennas, and the physical and electrical characteristics of some special types of VHF television antennas.

12-2. **Transmission and Propagation.** The transmission line provides the path for transferring signal energy from the TV transmitter to its antenna and for delivering the signal energy received by the antenna to a TV receiver. Propagation refers to the way the electromagnetic waves, representative of the TV signal, travel from the transmitting antenna to the receiving antenna. A knowledge of the characteristics of transmission lines and propagation is very important in TV work.

12-3. *VHF television transmission requirements.* The transmitter's frequency of operation depends upon its channel allocation (VHF channel allocations were discussed in Section 11). A transmission line must be capable of transferring signal energy from one point to another with minimum attenuation and without introducing any reactive components which would vary the characteristics of its input or output circuits. Also, a transmission line whould have negligible pickup along its length so that it will not introduce signals into the receiver other than those received signals coming from the antenna.

12-4. *Transmission lines.* An efficient transmission line must be selected with great care with respect to dimensions, length, and impedance matching. Failure to secure optimum conditions results in a noticeably pronounced decrease in picture and sound signals and an increase in noise interference. Two general types of transmission lines, the parallel-wire type and the coaxial cable, are used extensively in VHF TV installations.

12-5. A transmission line can be described in terms of its characteristic impedance (Z_o), determined by the diameter of the conductors and the spacing between them. You will recall that Z_o is the same regardless of the length of the line and is defined in electrical terms as $Z_o = \sqrt{\frac{L}{C}}$. Z_o is in ohms, L is the inductance per unit length in henrys, and C is the capacitance per unit length in farads.

12-6. A line terminated in a resistive load equal to Z_o is nonresonant, transfers maximum power, and contains no reflected energy. On the other hand, a line terminated in opens, shorts, capacitances, inductances, or resistances unequal to Z_o is resonant and has energy reflected back into it causing standing waves to be set up on the line. You have no doubt already noted that the measurement of standing waves on a transmission line yields information about its efficiency of operation.

12-7. Of the three types of inherent losses in a line—resistive, dielectric, and radiation—the radiation loss is likely to be the most variable. It is very important to note that radiation loss varies with frequency. A VHF or UHF transmission line is efficient only at the frequency for which it is designed. When used at frequencies higher than those for which it is designed, a line has greater losses.

12-8. *Radiation and propagation characteristics.* You will recall that the creative manner in which electromagnetic waves travel through space is called propagation. The direct-wave component of a VHF or UHF radiated field tends to travel in practically a "line-of-sight" manner, with minor refraction due to the lower atmosphere. A portion of the wave strikes the earth at some distance from the antenna, however, and is reflected upward. Increasing the height of a receiving antenna tends to decrease signal-voltage cancellation caused by ground-reflected waves.

12-9. **VHF Antennas, General.** The electrical and physical features of VHF antennas are uniquely determined and vary with operating frequency, power-handling capability, plane of polarization, and the desired radiation field pattern. The physical size of an antenna is determined primarily by its operating frequency and power-handling capability, whereas its shape and height are determined by the desired radiation field pattern. Since the effective authorized area of service, local terrain conditions, and power output level of transmitting equipment vary from installation to installation, the antenna system used is almost always custom designed and custom built.

12-10. *Function and requirements.* The function of the VHF television transmitting antenna is to radiate with essentially uniform efficiency at the frequency range of the channel it serves. To perform this function, the antenna must meet certain physical and electrical requirements.

12-11. The physical requirements of any VHF antenna system include adequate structural strength to withstand wind, snow, and sleet loads; low wind-resistant radiating elements; immunity to damage from lightning; and deicing facilities where needed. The most important electrical considerations of the VHF transmitting antenna include horizontal polarization of the radiated waves, omnidirectional horizontal radiation pattern, wide bandwidth, high gain, adequate insulation to handle peak voltages that will be applied to it, and vertical directivity to obtain the required effective radiated power in relation to the transmitter output. Satisfactory signal reception by VHF TV antennas is obtained by considering such antenna factors as broadband response, directional characteristics, elimination of unwanted signals and reflections, and antenna location. In our introductory discussion of the various properties of TV antennas, we are taking the simple dipole as the basic reference.

12-12. *Resonant wavelength.* The electrical (resonant) wavelengths of TV antennas differ from those of radio waves in free space. As the frequency of operation increases, radiation resistance and the effect of capacitance at the end of the antenna effectively reduce the resonant wavelength of an antenna. It is therefore necessary to cut TV antennas with a correction factor (usually 0.94). For example, let us assume we are designing an antenna for television channel 3, 60 to 66 MHz, using the midfrequency (63 MHz) in the design formula.

12-13. You will recall that a formula describing r-f propagation in free space is:

$$\lambda\ (\text{feet}) = \frac{984\ \text{feet}}{F\ (\text{MHz})}$$

Using the correction factor, 0.94, we can determine the physical length of the antenna which would operate with an effective wavelength equivalent to that of a 63-MHz signal:

$$\lambda\ (\text{feet}) = \frac{984\ \text{feet} \times 0.94}{63\ \text{MHz}}$$

$$\lambda = 14.5\ \text{feet}$$

A dipole antenna designed for channel 3 operation, therefore, should be 7.25 feet in length. It is often desirable to calculate the length of a dipole in inches. Here is a practical form of the formula (including a correction factor) commonly used for this purpose:

$$\frac{\lambda}{2}\ (\text{inches}) = \frac{5540\ \text{inches}}{F\ (\text{MHz})}$$

12-14. *Impedance.* The impedance at any point on an antenna is simply equal to the voltage at that point divided by the current at the point. A half-wave dipole antenna usually has an impedance of approximately 72 ohms at the center (input impedance), but its impedance may be several thousand ohms at the ends, with intermediate points having intermediate ohmic values. These values are valid only for the resonant frequency; for frequencies off resonance, the center impedance is greater.

12-15. Folded dipole antennas can be used to facilitate impedance matching with transmission lines. Each additional conductor of a folded dipole antenna increases the input impedance. If

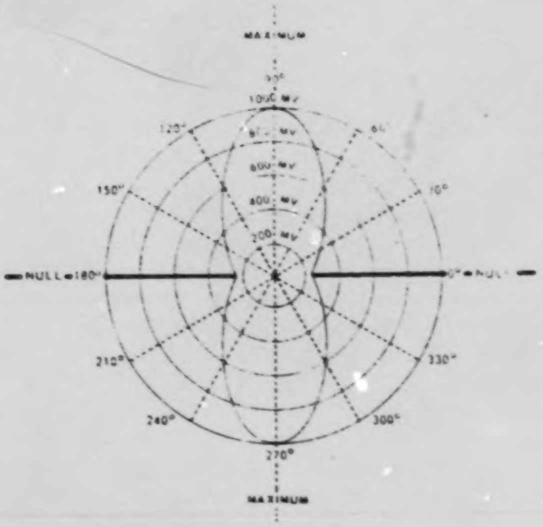


Figure 73. Radiation pattern of a horizontally mounted dipole antenna.

two conductors are used, the current is reduced to one-half its original value and the input impedance of the antenna increases to four times 72 ohms, or about 300 ohms. Therefore, a 300-ohm transmission line can be connected to the folded dipole and a correct Z-match will occur. If the added conductor has a larger diameter than the conductor to which the transmission line is connected, the impedance stepup produced by the folded dipole is further increased.

12-16. *Polarization.* You will recall that the polarization of a propagated electromagnetic wave depends upon the direction in which the electric field travels, with respect to the earth. A vertically mounted antenna radiates a vertically polarized wave, whereas a horizontally mounted antenna radiates a horizontally polarized wave. Horizontal mounting of the transmitting antenna in the clear at a high altitude substantially reduces the effects of the earth on the propagated wave. Better reception is usually obtained from a horizontally mounted receiving antenna because it is less susceptible to noise pickup.

12-17. *Directivity.* Antennas which radiate in all directions are referred to as omnidirectional. Since radio waves are electromagnetic in nature, they can be directed so that radiation either occurs in specific directions or is concentrated into a narrow band. The polar-coordinate graph is generally used in studying signal intensity or radiation patterns. Figure 73 is a polar representation of a horizontally mounted dipole antenna. The pattern may be used to interpret transmitting or receiving directivity characteristics.

12-18. The antenna characteristic that causes the antenna to radiate or receive more power in certain directions than in others is directivity. There are several methods of obtaining directional characteristics in an antenna. One method uses either driven or parasitic multielement arrays. Driven arrays are bidirectional, whereas parasitic arrays are unidirectional. Another method uses reflectors and directors. Still another uses a number of individual antennas connected together. A combination of methods may be used to achieve highly directional antennas. Such directional antennas form an important part of point-to-point communications, microwave link, and radio relay systems. Many TV systems utilize a microwave link between the studio and transmitting antenna. Microwave signals travel in straight lines. It is therefore possible to reflect and focus them in a manner similar to light waves. The use of highly directive antennas permits a small amount of energy at a transmitting point to produce a satisfactory signal at a distant receiving point.

12-19. The VHF TV broadcasting antenna is generally omnidirectional; however, the receiving antenna is generally directional and is oriented to have maximum sensitivity in the direction of the transmitting station. The directional receiving antenna has better sensitivity and less noise pickup than the omnidirectional antenna. Increasing directivity increases antenna sensitivity and tends to eliminate unwanted signals, wave reflections, and interference. Horizontal directivity can be achieved by placing one or more reflectors behind the antenna and directors in front of the antenna. Vertical directivity can be achieved by stacking antenna arrays one above the other. Some specific military application may require a directional transmitting antenna

12-20. *Gain.* The gain of an antenna depends upon its total radiation pattern and is a function of directivity. The gain of one antenna over that of any other antenna can be determined by observing the field strength of both antennas at a particular point. Generally, the basic half-wave (dipole) antenna is the standard against which other antennas are measured. When not specified otherwise, the figure expressing the gain of an antenna refers to the gain in the direction of maximum radiation, or reception. Gain is expressed in terms of decibels, with zero decibels (0 db) the standard for the gain of a dipole.

12-21. *Bandwidth.* For optimum service, the transmitting antenna should have a constant frequency response over the 6-mc bandwidth of its assigned TV channel. A single receiving antenna array is often used to receive many VHF TV channels. Reducing the Q of an antenna will increase its bandwidth. A reduction in Q also will lower the gain of an antenna. Methods employed to provide a wideband response and maintain gain may include:

- Folding elements.
- Increasing size and/or number of elements.
- Intricate phasing of elements.
- End-fire arrangements.
- Stacking of arrays.

12-22. **Factors Affecting Efficiency.** If antennas are to produce or collect electromagnetic energy in an efficient manner, they must be designed and mounted in a fashion which permits efficient operation. Let us now discuss some of the factors which are considered in the designing and mounting of VHF antennas.

12-23. *Design considerations.* The field pattern of a given antenna is the same for reception as for transmission. The functions of the transmitting and receiving antennas are, however, quite different. Transmitting antennas are designed for high efficiency in radiating energy, whereas receiving antennas are designed for the efficient pickup of energy. Some of the major factors considered in the design of antennas are (1) frequency of operation, (2) power-handling capabilities, and (3) desired beam pattern. Special types of antennas designed for specific purposes will be discussed in the last part of this section.

12-24. *Mounting considerations.* Since hills, buildings, and trees affect propagation and decrease efficiency, surrounding areas must be considered when installing antennas. Transmitting sites should be chosen to provide minimum bending of direct-path energy. Receiving antenna sites should be chosen to provide minimum reflections, shadow losses, absorption losses, and interference. The line-of-sight distance can be extended by increasing the height of either or both of the transmitting and receiving antennas. To assure optimum service to the maximum number of people, transmitting antennas are usually placed atop a high tower or mast which is itself on top of the highest building, mountain, or hill available. Since field strength depends upon height, increasing the height of receiving antennas results in stronger signal reception.

12-25. It is desirable to concentrate vertical radiation at small vertical angles to provide best coverage of the service area. VHF energy radiated at angles considerably higher than the line-of-sight path is wasted because it does not return to the effective path of signal transmission. VHF energy radiated downward toward the earth is either absorbed by the earth or reflected back to reduce signal strength or cause ghosting in the receiver. Vertical directivity can be readily achieved by stacking identical antenna arrays one above the other and feeding them in phase. Stacking antenna arrays concentrates sensitivity at smaller vertical angles. This arrangement also reduces noise pickup from the top and bottom of the antenna, thus improving reception sensitivity in the desired direction.

12-26. **Power-Handling Capabilities.** In order to assure the best possible TV service to the maximum number of people, the FCC limits both the maximum and minimum power which may be radiated by each broadcasting station. The antenna system must be capable of handling the peak power output of the picture and sound transmitters (peak power input of the antenna). Meeting this requirement demands consideration of power-handling capability when selecting a transmitting antenna. It should be understood that antenna input power and effective radiated power (ERP) are not the same. Basically, ERP is the product of the antenna input power and antenna gain. In other words, a relative medium antenna input applied to a high-gain antenna may be as effective as a high power output applied to a low-gain antenna. The maximum ERP for a TV station is established with reference to the visual transmitter. Channel assignment and antenna height become factors in ERP standard. The transmitting antenna must be properly insulated to withstand the peak voltages of the transmitters it serves. However, insulation of the receiving antenna presents no problem because received signal strength is never over a few microvolts.

12-27. **Impedance Matching.** The impedance of the transmission line serving an antenna system must be matched to the antenna it serves. You will recall that there is a maximum transfer of energy only when the impedances of load and generator circuits are both resistive and equal. Transmitting antennas are designed to radiate with uniform efficiency over the frequency of the range of the assigned channel. With proper impedance match to the transmission line, an antenna will radiate all of its input power, except for the portion dissipated thermally in the antenna conductors. Defective termination causes reflections to occur at the antenna terminals and standing waves on the transmission line. Since the standing-wave ratio for any given sideband component is a function of frequency, the signal reaching the antenna suffers from frequency and phase distortion in addition to attenuation.

12-28. Matching of the characteristic impedance of the transmission line with the input impedance of the receiver is important from the standpoint of maximum signal transfer. This is especially true in weak signal areas. In addition to attenuating signal strength, reflections due to mismatching at the receiver input terminals produce double image effects on the picture screen (ghosts). Matching at the receiver input (usually 72 or 300 ohms) is done by using a transmission line with a corresponding value of characteristic impedance. In strong signal areas, close matching of the antenna to the transmission line is not as important because the mismatch results merely in a slight loss of signal strength; however, in this case, the transmission line and receiver input impedances should be matched.

12-29. **Baluns.** There are two types of lines or circuits—balanced and unbalanced. The two conductors of a balanced transmission line have equal resistance per unit length and equal impedance from each conductor to ground and to other electrical circuits. Antennas are usually balanced; that is, they are symmetrically constructed with respect to the feed point. Twin lead transmission lines are balanced. The use of shielded twin leads does not disturb the balance because the shield does not act as a conductor for the signal energy. A coaxial cable transmission line is unbalanced. Its outer conductor has a much larger surface area than the inner conductor, causing the line to be inherently unbalanced. The connection between the coaxial line and the antenna must be made without upsetting the symmetry of the antenna itself. This requires a circuit that will isolate the balanced load from the unbalanced line while providing efficient power transfer. The device which performs this function of converting balanced to unbalanced feed systems, or vice versa, is called a balun. The word is a contraction of balanced-to-unbalanced.

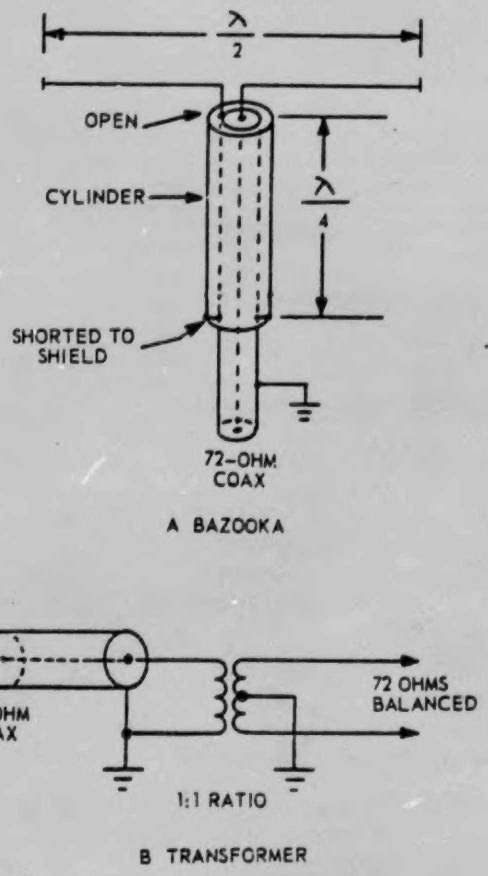


Figure 74. Bazooka balun.

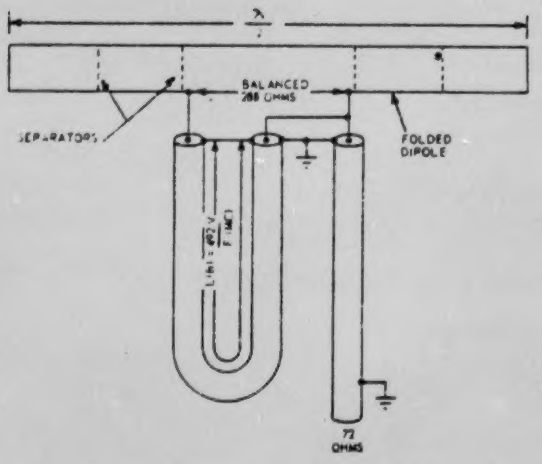


Figure 75. Coaxial balun.

12-30. *Bazooka balun.* A satisfactory connection can be made with a bazooka, or line-balance converter, as shown in figure 74. In the coaxial line, the center conductor corresponds to the hot lead; that is, it has a high r-f potential and is at some impedance to ground. The purpose of the bazooka is to raise the outer conductor to a high impedance above ground. Through the use of a quarter-wave shorted cylinder, the impedance between the outer conductor and ground can be increased to the required value (fig. 74, A). This quarter-wave cylinder is connected directly to the outer conductor of the coaxial line and is short circuited at this point as shown. Since the cylinder is a quarter-wavelength long, it presents a high impedance at the open end. Therefore, the shield is isolated from ground (electrically one-quarter wavelength) and can be connected to one wire of a balanced line or antenna. The action of the bazooka is similar to that of the transformer shown in figure 74.B. The primary is grounded at one end, while the secondary is grounded at the midpoint of the winding.

12-31. *Coaxial balun.* Another method of connecting a coaxial cable to a balanced transmission line or a balanced antenna—while at the same time having a 4-to-1 impedance stepup—is shown in figure 75. Equal and opposite voltages, balanced to ground, are taken from the inner conductor of the main transmission line and half-wave phasing sections. Since the voltages at the balanced end are in series while the voltages at the unbalanced end are in parallel, there is a four-to-one step down ratio in impedance from the balanced to the unbalanced side.

12-32. **VHF Antennas, Special Types.** An important principle in the study of antennas is that the characteristics of an antenna used for transmitting are much the same as when the antenna is used for receiving. Some of the practical differences between them are directional characteristics, power-handling capabilities, weather protection, and elevation. A VHF TV transmitting antenna should be omnidirectional and radiate a broadband signal. Some factors which affect the choice of receiving antennas are direction and range of the station or stations to be received, channel frequency of the transmitting station, noises and interferences prevalent in the surrounding area, and relative signal strength.

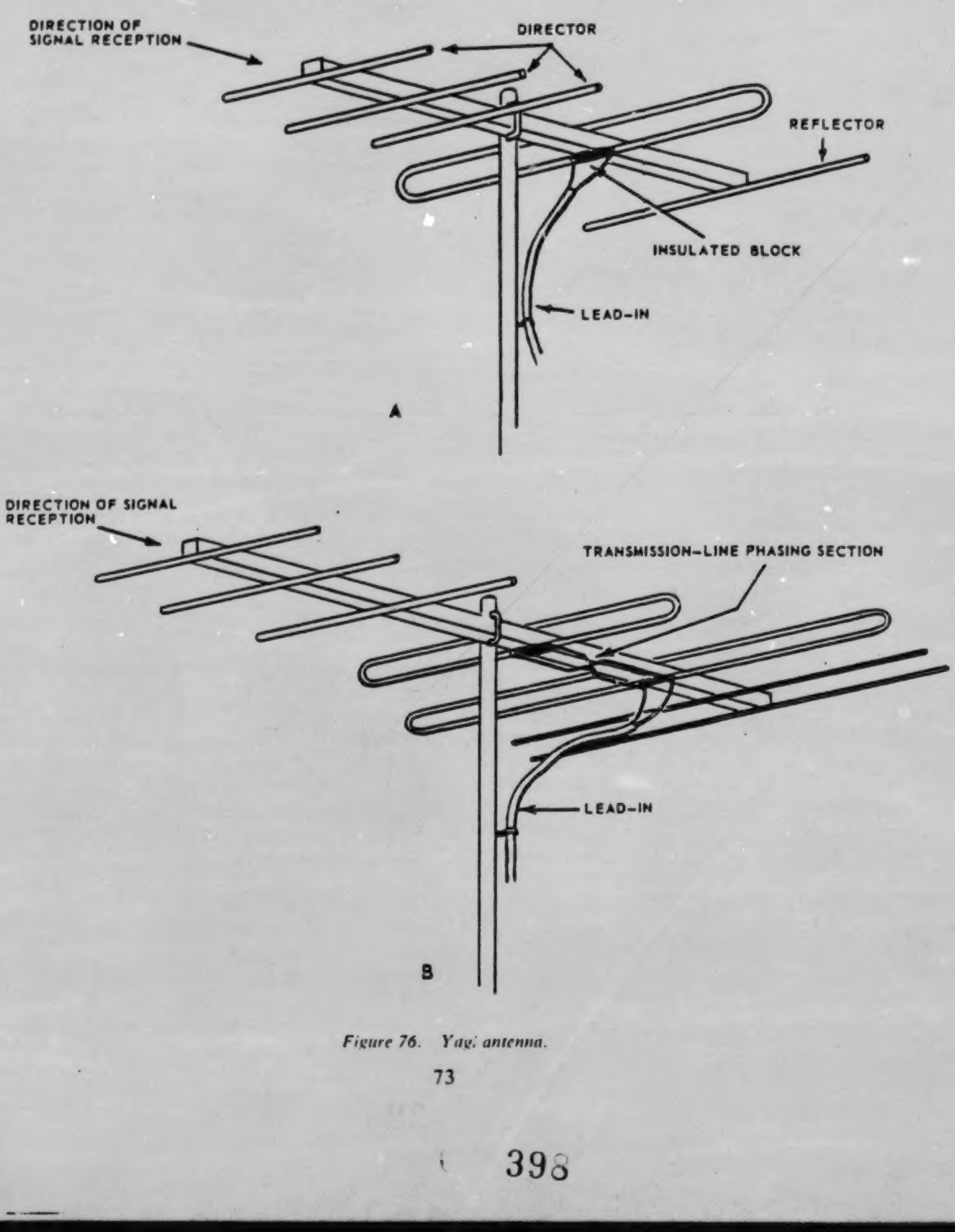

DIRECTION OF SIGNAL RECEPTION
DIRECTOR
REFLECTOR
INSULATED BLOCK
LEAD-IN
A
DIRECTION OF SIGNAL RECEPTION
TRANSMISSION-LINE PHASING SECTION
LEAD-IN
B

Figure 76. Yagi antenna.

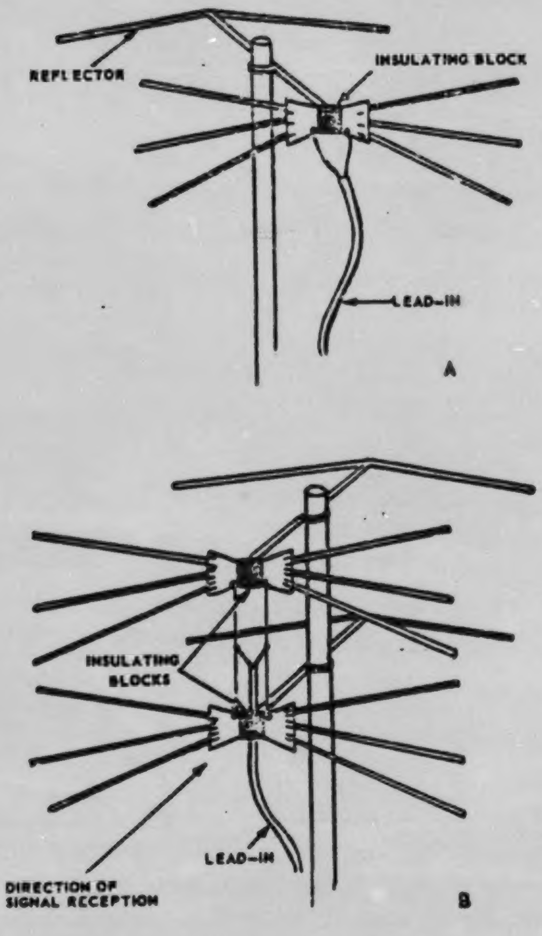


Figure 77. Conical antenna.

12-33. The choice of an antenna is sometimes a matter of compromise. Many types of antennas, ranging from the modified basic dipole to more complex wideband arrays, are used today in TV. Our discussion of the characteristics of VHF TV receiving antennas will include the Yagi, conical, and log-periodic types, whereas the discussion of transmitting antennas will include the turnstile, traveling-wave (slot type), and helical types.

12-34. *Yagi antenna.* The Yagi antenna is one of the most popular TV receiving antennas. Its characteristics are high gain, sharp unidirectional response pattern, good front-to-back ratio, and relatively narrow bandwidth. The Yagi antenna is an array consisting of a driven element (dipole) with one reflector and two or more directors. The radiator may be either a simple or folded dipole. Additional reflectors do not improve reception. The more directors used, the greater the gain; however, the gain does not increase directly with the number of elements. Also, adding elements will decrease the impedance of the array.

12-35. The simplest Yagi, such as the one illustrated in figure 76.A, is most effective for a single channel (6-mc bandwidth). Because of its high gain and high front-to-back ratio, it is particularly effective in a weak signal area. In many locations, however, the single-channel antenna is outmoded because of the greater number of TV channels occupied. Wideband Yagi antennas have been developed for use in areas where several distant stations that are close in frequency lie in the same general direction.

12-36. The basic plan for the wideband Yagi is illustrated in figure 76.B. The driven elements are folded dipoles which may be the same or different overall lengths. However, they must be properly spaced and fed to make the system resonant and maintain a constant impedance over a very broad band of frequencies. The length of the elements must be properly measured and spaced to provide wideband service. A typical wideband Yagi employs two folded dipoles of different lengths which are fed by a transmission-line phasing section between the dipoles. A double reflector is used to obtain the most suitable front-to-back ratio over the wide band of frequencies to be received. A group of two to four directors can be placed in front to obtain peak gain and good front-to-back ratio at the high-frequency end of the band to be received. An additional parasitic element may be inserted between the driven dipoles to act as a reflector at the high end and as a director at the low end of the frequencies to be received. It is possible to cover the entire TV spectrum with three or four wideband Yagis.

12-37. *Fanned type conical antenna.* One of the most effective of all VHF channel TV receiving antennas is the fanned type conical, shown in figure 77.A. The low Q needed to obtain broadband characteristics is obtained in this antenna by the large cross-sectional area produced by spreading or fanning out the elements. The six-element conical with reflector has an improved gain at the high ends of the low- and high-band channels. In general, the conical type antenna must be oriented carefully on the low band to prevent picture smear and on the high band to prevent echoes in the picture. High-band orientation is critical because of the sharper directional antenna lobes and the presence of strong minor lobes that introduce reflection or signal interference. The gain of the conical type antenna can be raised and the vertical directivity pattern improved by stacking two to three combinations of the basic type, as shown in figure 77.B.

12-38. *Log-periodic antenna.* The log-periodic antenna is a recently developed broadband, high-gain, highly directive antenna. The operational and design characteristics of a log-periodic antenna are such that input impedance, radiation pattern, and the active elements must repeat periodically as a function of the logarithm of frequency.

12-39. Design parameters for a planar type log-periodic dipole are shown in figure 78. The two half structures are fed one against the other in a horizontal plane. A balanced-line feeder is used in the illustration. The length of each successive dipole element forms a geometric progression with a common ratio of less than one. This common ratio is usually referred to as tau (τ). Tau, called the scale factor, determines the periodicity (spacing) and the number of elements. As the number of elements is increased, the directivity, front-to-back ratio, gain, and input impedance increase. The longest element, l_m, is approximately ½ wavelength, $\frac{492}{F_{mr}}$, at the lowest operating frequency, and the shortest element is ⅜ wavelength at the highest operating frequency.

12-40. The limiting factor of tau is the angle phi (ϕ). Angle ϕ defines or limits the length of each succeeding dipole element since ϕ is dependent upon the length of the longest element, the length of the shortest element, and tau. As the angle ϕ increases, the directivity, front-to-back ratio, gain, and input impedance decrease. Therefore, in the design of the log-periodic antenna, the angle ϕ and the geometric ratio tau are a compromise for directivity, front-to-back ratio, gain, and input impedance. The angle alpha (α) is ½ the angle ϕ and is used in the design charts for a log-periodic antenna. Sigma (σ) is the spacing factor and is the ratio of the distance between two adjacent elements to twice the length of the longest element. The geometry of the log-periodic antenna relating sigma to tau and alpha is $\sigma = \frac{1}{4}(1 - \tau) \cot \alpha$.

12-41. *Turnstile antenna.* In both low- and high-band VHF applications, the transmitting antenna usually consists of several individual radiating elements arranged one above the other to obtain the necessary gain, directivity, and desired bandwidth. The superturnstile arrangement, shown in figure 79, is an example of this type

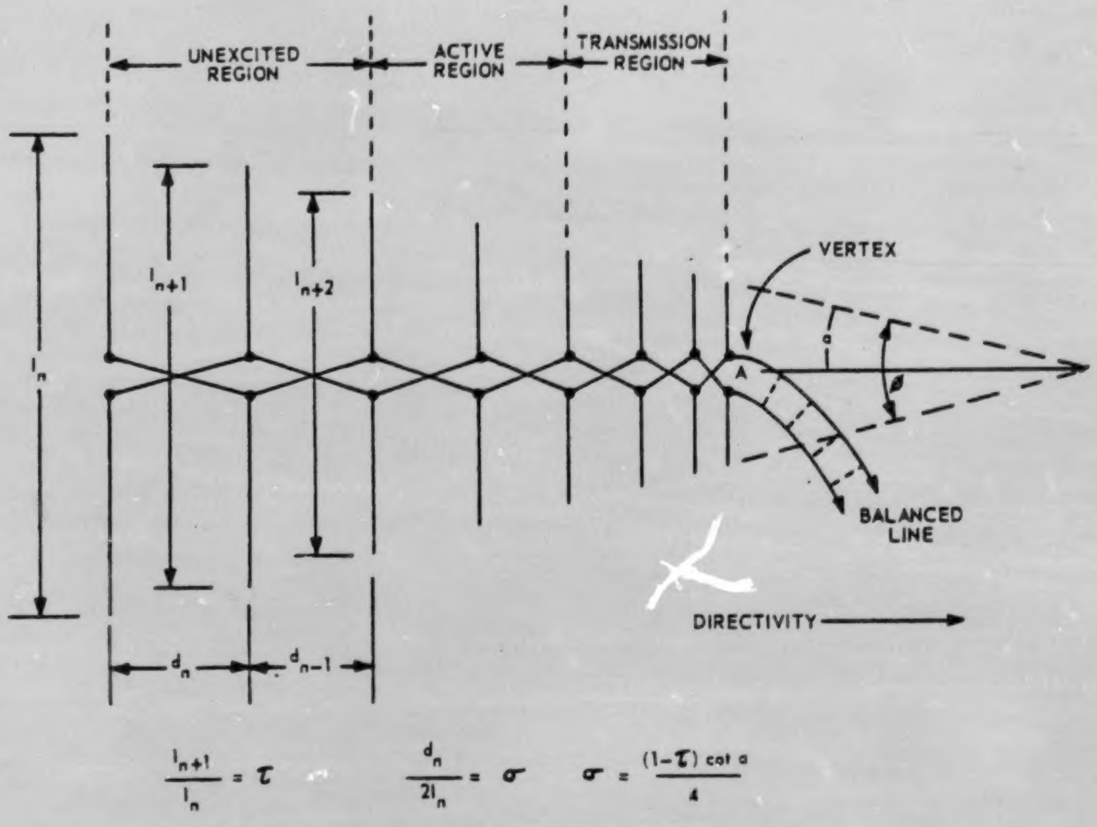


Figure 78. Log-periodic antenna.

of antenna design Each stacked array provides additional signal gain for the TV system. Gain for low-band VHF antennas is usually limited to 10 db or less, whereas high-band VHF antennas are designed for gains as high as 20 db. A TV system utilizing an antenna having a gain of 10 db can realize an approximate ERP of 50 kw with a video transmitter output of 5 kw.

12-42. The turnstile antenna receives its name from its physical shape. The basic turnstile antenna consists of two horizontal half-wave antennas mounted at right angles to each other in the same horizontal plane. When these two antennas are excited with equal currents 90° out of phase, the typical figure-eight patterns of the two antennas merge to produce to the nearly circular pattern shown in figure 80.A. When two pairs (bays) are stacked 1/2 wavelength apart and the corresponding elements excited in phase, as shown in figure 81, a part of the vertical radiation from each pair cancels that of the other pair. By stacking a number of bays, the vertical radiation pattern can be altered to obtain substantial gain in all horizontal directions without altering the overall horizontal directivity pattern. Figure 80.B. compares the circular vertical radiation pattern of a single-bay turnstile with the sharp pattern of a four-bay turnstile array. A three-dimensional radiation pattern of a four-bay turnstile antenna is shown in figure 80.C.

12-43. *Superturnstile antenna.* As previously mentioned, the superturnstile antenna, shown in figure 79, is a popular VHF transmitting antenna. Its radiating elements are constructed to produce horizontal polarization of the radiated signal. Since the radiating elements are slots, slot radiation theory is the fundamental principle involved in the operation of the antenna system. Let us consider slot theory by examinng a flat sheet of metal in which a narrow slot has been cut; the slot is the width of a half-wave dipole and is a quarter-wavelength long (fig. 82.A). The radiation pattern produced by the antenna (slot) cut into an infinitely large metal sheet and that of the complementary dipole antenna are the same. However, it is interesting to note two important differences between the slot antenna and its complementary antenna. First, the electric and magnetic fields are interchanged. In the case of the dipole antenna shown, the electric lines are horizontal, while the magnetic lines form loops in the vertical plane. With the slot antenna, the magnetic lines are horizontal and the electric lines are vertical. These electric lines are built up across the narrow dimension of the slot. As a result, the polarization of the radiation produced by a horizontial slot is vertical, whereas polarization of a radiated wave produced from the

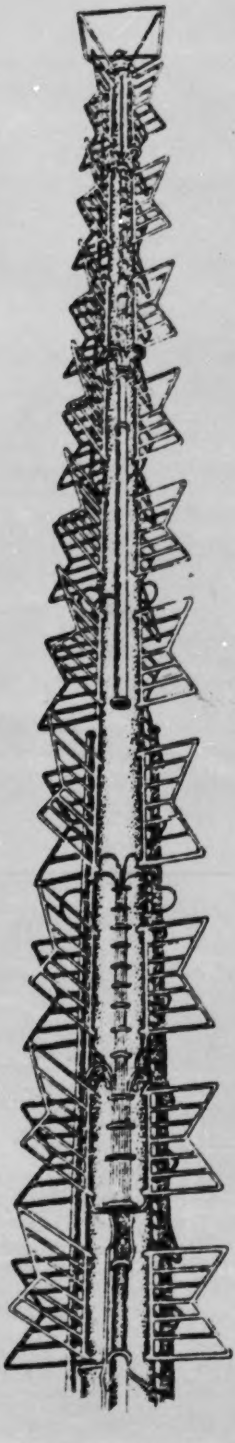


Figure 79. Superturnstile antenna.

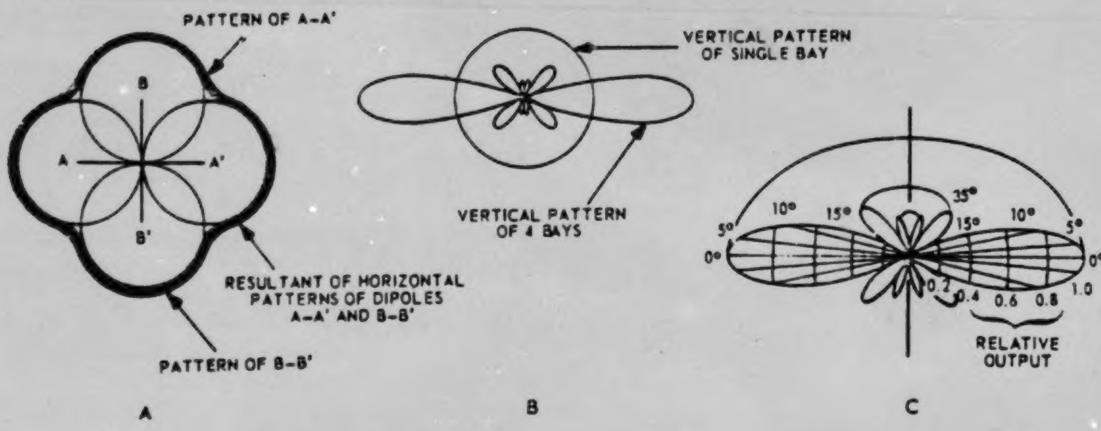

PATTERN OF A–A'
B
A
A'
B'
RESULTANT OF HORIZONTAL PATTERNS OF DIPOLES A–A' AND B–B'
PATTERN OF B–B'
A
VERTICAL PATTERN OF SINGLE BAY
VERTICAL PATTERN OF 4 BAYS
B
35°
10°
15°
15°
10°
5°
5°
0°
0°
0.2
0.4
0.6
0.8
1.0
RELATIVE OUTPUT
C

Figure 80. Turnstile antenna radiation pattern.

vertical slot is the same as that produced by a horizontal dipole. The plates may be considered to be a horizontal dipole, 1/2 wavelength wide and 1/4 wavelength long, being fed at the center. When energy is applied to the slot antenna, currents spread over the entire sheet and flow in a direction parallel to the small side of the plates. Radiation then takes place from both sides of the metal sheet as in the case of the horizontal dipole. Since radiation resistance causes the magnitude of the current to decrease rapidly from the slot, the plates need be cut only 1/4 wavelength long. The radiation current becomes negligible 1/4 wavelength from the slot.

12-44. The actual form in which the elements are generally constructed is shown in figure 82,B. The open construction shown has no effect on the electrical characteristics of the antenna but is very advantageous in reducing wind resistance. The horizontal conductors are made smaller at the center (giving the batwing appearance) to increase the current at the top and bottom in relation to that at the center of the radiating surface; thus, horizontal directivity of the radiation pattern is increased. At the same time, the impedance characteristic is broadened, making it more constant over a wide band of frequencies. Horizontal coverage of the serviced area is increased by feeding the antenna pairs 90° apart in phase. The 90° phase difference is achieved by feeding one group of antenna elements (E-W or N-S) with a transmission line 1/4 wavelength longer than the transmission line feeding the opposite group.

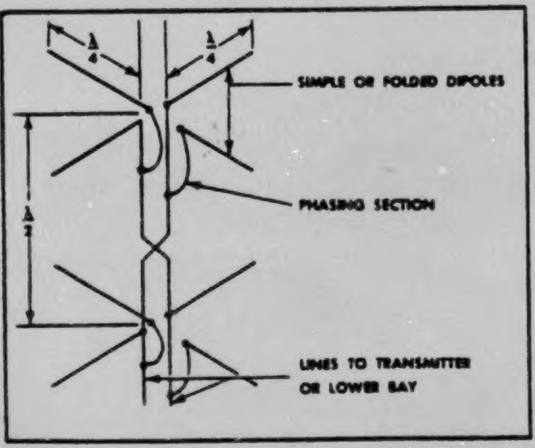


Figure 81. Stacked turnstile antennas.

12-45. *Traveling-wave antenna.* The transmitting antenna, shown in figure 83, also uses the slot radiation principle. The design is similar for high-band VHF and UHF TV transmission. The name "traveling-wave" comes from the way the slots in the antenna are fed. Through the traveling-wave method of feeding the slots, high antenna gain is obtained without using a large number of feeder lines. Because the physical size of the slots in relation to wavelength is much smaller at the higher frequencies, it is possible to design these antennas for gains of 9 to 60, depending upon the frequency of operation. An ERP of 1 million watts may be achieved in UHF practice with an r-f carrier of 25 kw driving a 60-db antenna. The maximum radiated power authorized for UHF transmission is 5 million watts.

12-46. The radiating elements consist of a series of 1/2-wavelength slots, four to a layer, equally spaced at 90° intervals around the circumference of the mast. Additional layers of slots may be added at 1-wavelength distances, measuring from the center of the slots. Each layer of slots is rotated 45° with respect to the preceding layer to achieve the necessary horizontal omnidirectional radiation pattern. The number of layers of slots, as in the case of superturnstile batwings, will determine the approximate gain of the antenna system.

12-47. A copper tube, mounted coaxially within the steel tube, acts in conjunction with the steel tube as the center conductor of a coaxial line. Probes mounted inside the steel tube at one side of the center of each slot are oriented toward the conductor in a manner that will cause excitation of the slots. The traveling-wave method of feeding the slots is accomplished by capacitively feeding the r-f energy from the center conductor to the slots by way of the probes. The excitation from the slots forms the radiated signal pattern necessary to service a given area. Broadband requirements are met by placing additional probes between each layer of slots.

12-48. *Helical antenna.* Another specially- designed TV transmitting antenna is the helical type, consisting of a coil quite similar to a large-size air-core inductor. It can be made to have maximum radiation either in the axial direction or in a direction normal (perpendicular) to the axis, depending upon the circumference of the helix and its pitch. If the helix is constructed so that the length of one turn is approximately 1 wavelength and the spacing between turns is approximately 1/4 wavelength at the center of the operating frequency band, the radiation pattern will be like that shown in figure 84.A. A radiation pattern in the normal mode, like that shown in figure 84.B, occurs if the helix dimensions are small in comparison with a wavelength.

12-49. Helical antennas are generally used on the high VHF band and UHF channels. The VHF helical antenna in its popular form is essentially a coil of uniform pitch wound around a circular mast section of uniform outside diameter. A typical VHF helical antenna is shown in figure 85.

12-50. When excited with r-f energy, a wave is established which travels between the helix wire and the ground plane formed by the mast. The wave travels around the circumference of the mast, and, because of the pitch of the helix, progresses up or down the axis of the helix. This causes the entire length of the helix to serve both as a radiator and as a feeder for successive portions of the antenna. The radiated beam is maximum at right angles to the helix axis. Successive turns of the helix work together to produce side-firing fields that form the radiated beam. Because of structural considerations, a 2-wavelength turn is most commonly used. Helical antennas for channels 7 to 13 are built in a standard series having gains of 4 to 25, depending upon the number of bays used. A one-bay antenna can be used with transmitter powers up to 100 kw.

12-51. **Color Television Antenna Requirements.** The requirements of an antenna for color reception are quite similar to those for black and white reception. In general, an antenna

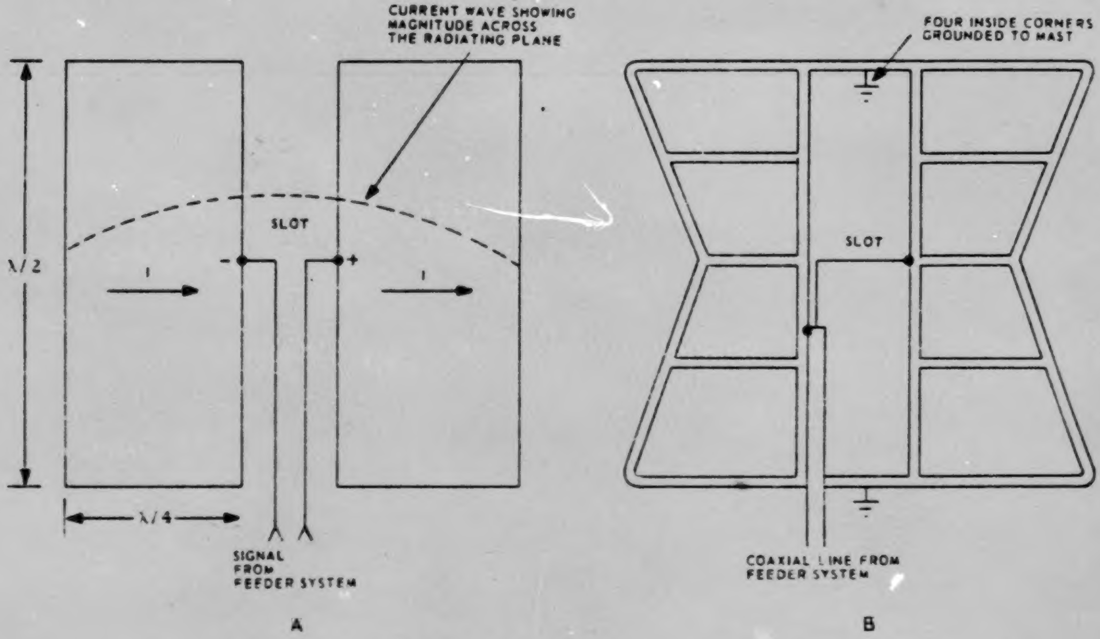

CURRENT WAVE SHOWING MAGNITUDE ACROSS THE RADIATING PLANE
λ/2
SLOT
I
I
-
+
λ/4
SIGNAL FROM FEEDER SYSTEM
A
FOUR INSIDE CORNERS GROUNDED TO MAST
SLOT
COAXIAL LINE FROM FEEDER SYSTEM
B

Figure 82. Superturnstile element characteristics.

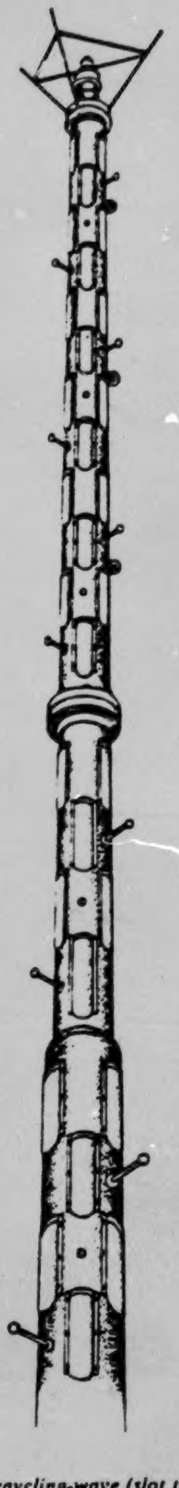


Figure 83. Traveling-wave (slot type) antenna.

which delivers a clear sharp picture, free of interference, reflections, and noise on black and white, will provide an excellent color picture. Almost all standard designs of broadband antennas have more than adequate bandwidth if properly installed. However, a narrowband antenna, such as the Yagi, will have sharp dips in the response curve at certain frequencies which will alter color reception on the channel involved.

12-52. The directivity requirement is the same for color as for black and white reception. The narrow beamwidth is required as an aid in discriminating against reflections. Reflections cause hues and shades to vary in the color picture, and may also cause partial or complete cancellation of the color subcarrier "burst" if the reflected path is an odd multiple of a half-wavelength at the transmitted subcarrier frequency. Good directivity can reduce interference pickup.

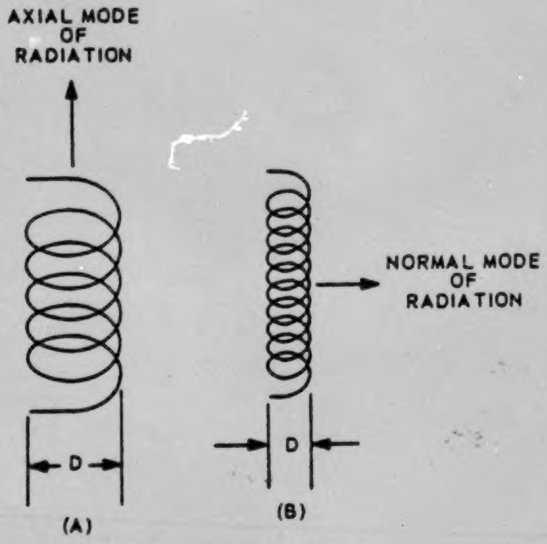


Figure 84. Helical antenna showing effect of pitch and diameter on direction of maximum radiation.

12-53. The gain and impedance matching requirements are also the same as those for black and white. Sufficient gain to produce a noise-free picture as required and the impedance must be matched between the transmission line and the receiver.

13. VHF TV Receivers

13-1. Since VHF TV receiver circuits are like those you find in other kinds of high-frequency equipment, you can apply much that you already know to this subject. For example, you already know about amplification and detection of AM and FM signals. Your study of TV transmission

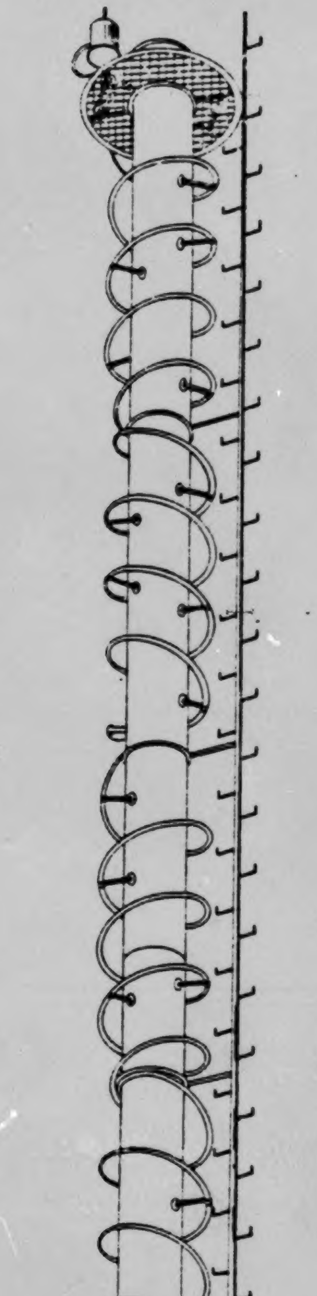


Figure 85. *Center-fed helical antenna.*

principles showed you that the composite video signal amplitude modulates the TV transmitter output. Also, you learned how the sound information frequency-modulates the separate sound transmitter output. Considering the different components that make up the composite video signal and the fact that amplification and detection of both video and sound information must be done simultaneously, you can easily see that the TV receiver is more complex than a radio receiver.

13-2. **Sections.** The TV receiver consists of ten distinctive sections, as shown in figure 86. These sections are the r-f, i-f, video, sync separator, vertical sweep, horizontal sweep, high voltage, low voltage, automatic gain control (agc), and audio. The antenna picks up the video and sound signals and applies them to the r-f section. Since the combined signals have a bandwidth of 6 MHz, the r-f section and antenna must deliver a linear response to the wide band of frequencies.

13-3. The composite signal is applied to a mixer stage where it is combined with a signal from the high-frequency oscillator. The resultant signal conversion will produce the desired intermediate frequency (i-f) signals. From this point the path of the signal will differ, depending on whether the receiver is of the *conventional* or *intercarrier* type.

13-4. In the conventional receiver the video and sound signals are separated after the mixer stage and are fed to their respective i-f amplifiers. The sound signal goes to an FM detector, commonly known as a discriminator. The video signal goes to an AM detector, the output of which is amplified by the video amplifier stage and then sent to the picture tube.

13-5. In the intercarrier receiver the video and sound signals are separated after passing through a common i-f amplifier system. A sound i-f of 4.5 MHz is taken off at some point past the video detector, then coupled through a bandpass filter network to the input of the sound i-f or FM detector.

13-6. The video signal consists of the picture signal with blanking pulses and synchronizing (sync) signals. (You should be familiar with these signals from your study of TV monitors in Volume 1, Chapter 5, of this course.)

13-7. *Tuner section.* The r-f section (tuner) has several important functions to perform. This section must select the desired TV channel, consisting of the sound and video carriers. It must convert these signals to an i-f signal for amplification. In most receivers an r-f stage is used to increase amplification of the signal before it reaches the mixer. The r-f amplifier acts as a buffer between the oscillator and antenna and prevents the retransmitting of extraneous signals. This type of extraneous retransmission can, of course, cause interference to other local TV receivers.

13-8. The r-f section must be of wideband design if it is to provide linear response over a 6-MHz range. Since the circuits must be wideband, the efficiency will be low, and the proper choice of parts and values is essential if we are to have satisfactory results. The layout of the chassis and components, the inductance and capacity of leads, plus the interelectrode capacitance of tubes become important factors in wideband circuits. The use of miniature tubes, carefully positioned parts, and all leads as short and direct as possible satisfy the wideband circuit requirements to some extent.

13-9. The r-f tuners have band switching circuits which are used for channel selection. Although there are many methods of band switching, the turret type and various switch types are the most popular. The r-f tuner is controlled by the channel selector switch. As we turn the channel selector switch, we select the proper tuned circuits, r-f mixer, and local oscillator for each individual channel. In addition, we also have a fine tuning control in the r-f section. This control varies the local oscillator frequency for proper centering of the video and sound signals in the i-f. bandpass.

13-10. *I-f section.* The i-f output of the mixer stage will be increased in amplitude by several stages of amplification. The i-f frequency may be anywhere from 19 MHz in some models to 45 MHz in others. The sensitivity and selectivity of the TV receiver are determined mainly by the number of stages of amplification. Once again, as in the case of the r-f section, the i-f amplifiers must have wideband characteristics. The i-f response must be flat over at least a 3-MHz range and should be flat over a 4-MHz range. Although there is a sacrifice of gain for the wideband requirement, three to five stages of i-f amplification will produce the necessary gain.

13-11. Video and sound separation is accomplished with resonant circuits in the output of the mixer or in one of the earlier i-f stages in the conventional receiver. In the intercarrier receiver, the video and sound separation is accomplished in the video detector or video ampli-

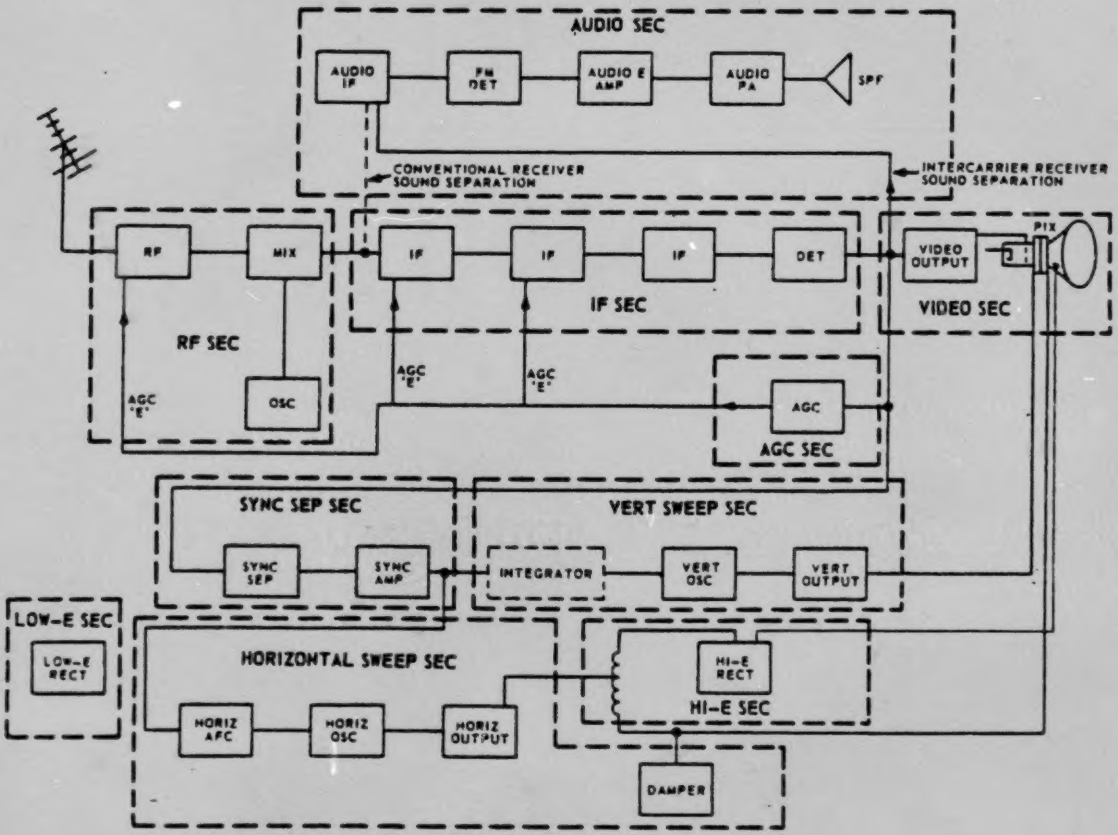

AUDIO SEC
AUDIO IF
FM DET
AUDIO E AMP
AUDIO PA
SPK
CONVENTIONAL RECEIVER SOUND SEPARATION
INTERCARRIER RECEIVER SOUND SEPARATION
RF
MIX
IF
IF
IF
DET
VIDEO OUTPUT
PIX
IF SEC
VIDEO SEC
RF SEC
AGC "E"
OSC
AGC "E"
AGC "E"
AGC
AGC SEC
SYNC SEP SEC
VERT SWEEP SEC
SYNC SEP
SYNC AMP
INTEGRATOR
VERT OSC
VERT OUTPUT
LOW-E SEC
LOW-E RECT
HORIZONTAL SWEEP SEC
HI-E RECT
HI-E SEC
HORIZ AFC
HORIZ OSC
HORIZ OUTPUT
DAMPER

Figure 86. Television receiver block diagram.

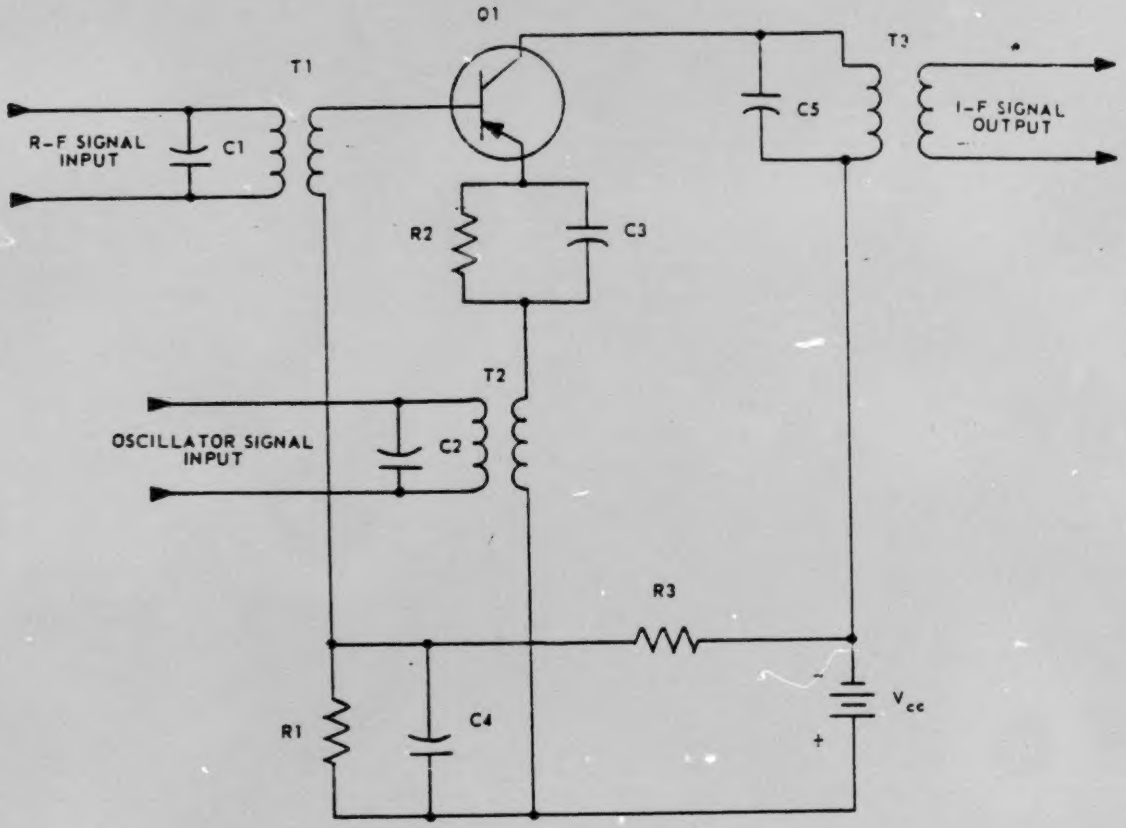

Q1
T1
T3
R-F SIGNAL INPUT
C1
C5
I-F SIGNAL OUTPUT
R2
C3
T2
OSCILLATOR SIGNAL INPUT
C2
R3
-
Vcc
+
R1
C4

Figure 87. Mixer stage.

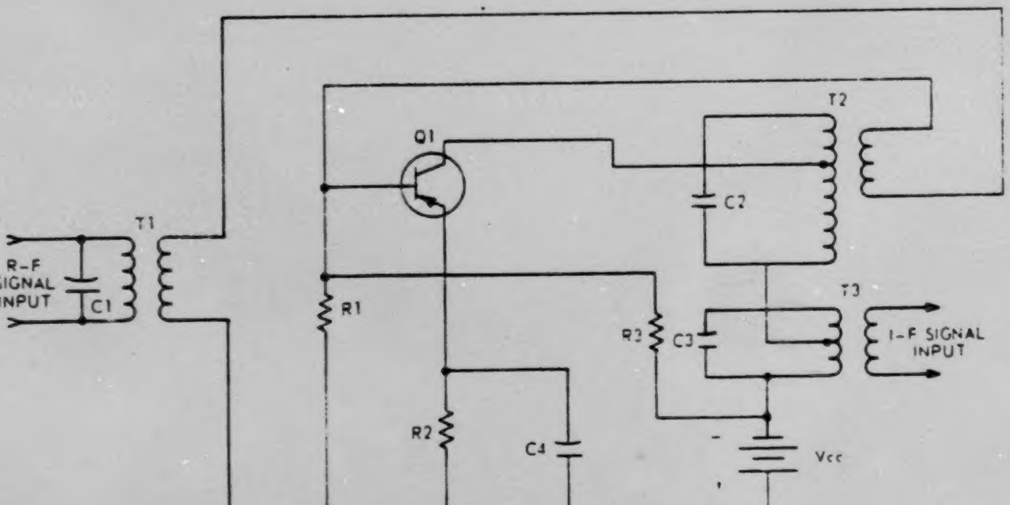

T2
Q1
C2
T1
R-F SIGNAL INPUT
C1
R1
R3
C3
T3
I-F SIGNAL INPUT
R2
C4
-
Vcc

Figure 88. Converter stage

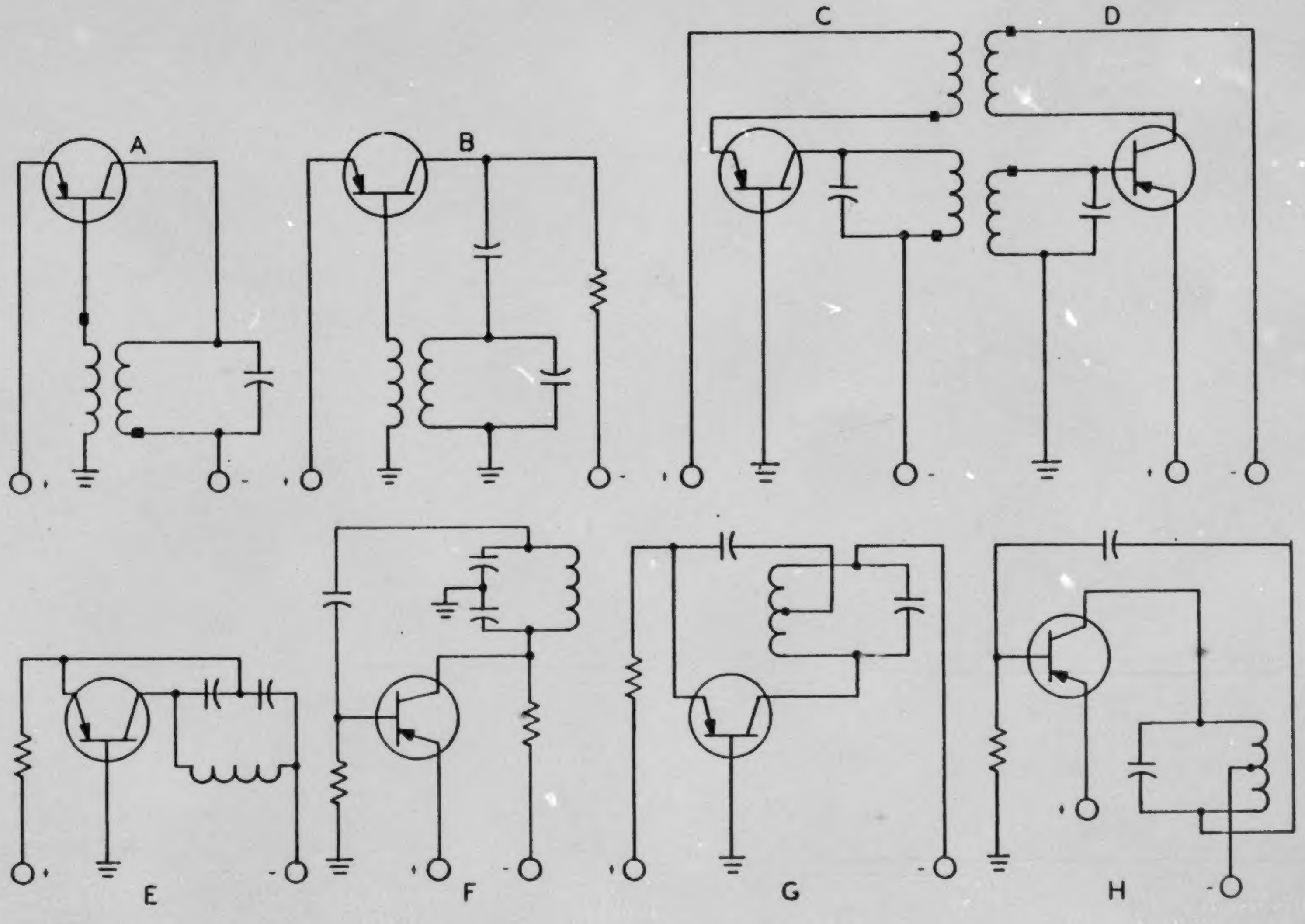


Figure 89. Basic oscillator circuits.

fier stage. In the latter case, the video and sound i-f carriers are amplified together through the i-f section. Automatic gain control (agc) is applied to all the i-f amplifiers except the last (normally). Also, agc is applied to the r-f amplifiers to control variations in signal strength.

13-12. Transistor r-f and i-f amplifiers have to take into consideration the internal capacitances of transistors which provide feedback paths for high frequencies. For this reason, there are certain features peculiar to transistor r-f and i-f amplifier configurations which must be considered. The common-emitter (CE) amplifier offers the highest power gain, better than 10 db above the common-base (CB) type. The CB amplifier cannot be discounted because its power gain is substantial and often adequate. Because power gain is usually a major requirement for high-frequency applications, the relative low-power gain of the common-collector (CC) amplifier detracts greatly from its usefulness. Since the CE amplifier has more feedback than the CB amplifier, the CB amplifier is preferred where stability, accurately controlled gain, and interchangeability are required.

13-13. All things considered, the CE configuration is generally selected for r-f and i-f amplifiers. The CB configuration is used when feedback must be kept to an absolute minimum.

13-14. *Mixer section.* A schematic diagram of a mixer stage with typical component arrangement is shown in figure 87. The r-f injected into the base circuit and the oscillator frequency injected into the emitter circuit are heterodyned in mixer Q1. The intermediate frequency is selected by the collector tank circuit. The intermediate frequency is then coupled through transformer T3 to the following stage. As you can see, this is a relatively simple circuit compared to a tube stage.

13-15. *Converter section.* The converter stage diagram is shown in figure 88. The r-f signal injected into the base circuit and the oscillator frequency generated by converter Q1 are heterodyned in the converter. The parallel-resonant circuit, consisting of capacitor C3 and the primary of transformer T3, selected the desired i-f frequency. The i-f is then coupled through transformer T3 to the following stage.

13-16. Capacitor C1 and the primary of transformer T1 form a parallel-resonant circuit for the r-f which is coupled through the transformer to the base circuit of converter Q1. Resistor R1 develops the emitter-base bias, and resistor R3 is a voltage dropping resistor. Resistor R2 is the emitter swamping resistor, and capacitor C4 is a bypass for the r-f. Capacitor C2 and the primary of transformer T2 provide the required feedback for the oscillator portion of converter Q1. Capacitor C3 and the primary of transformer T3 form a parallel-resonant circuit for the i-f which is coupled through the transformer to the following stage. The primaries of transformers T2 and T3 are tapped to obtain the desired selectivity.

13-17. *Oscillator section.* Illustrated in figure 89 are basic circuits which show component arrangements and polarity applications for p-n-p type transistor oscillators. N-p-n type transistors may be substituted in any of the circuits as long as the d-c polarities are reversed. Each circuit provides amplification, regenerative feedback, and inductance-capacitance tuning. Exact bias

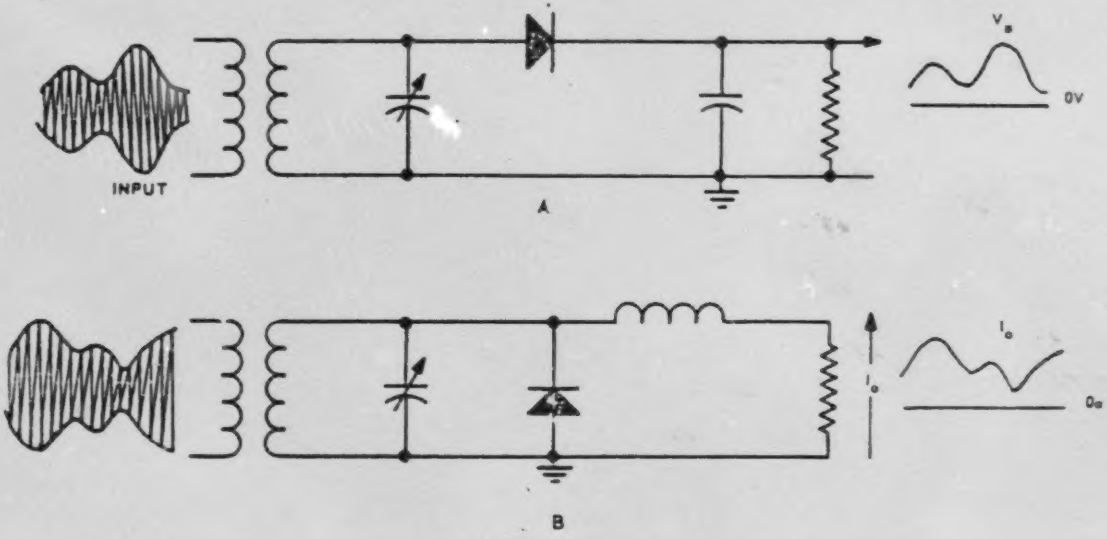


Figure 90. Diode AM detector.

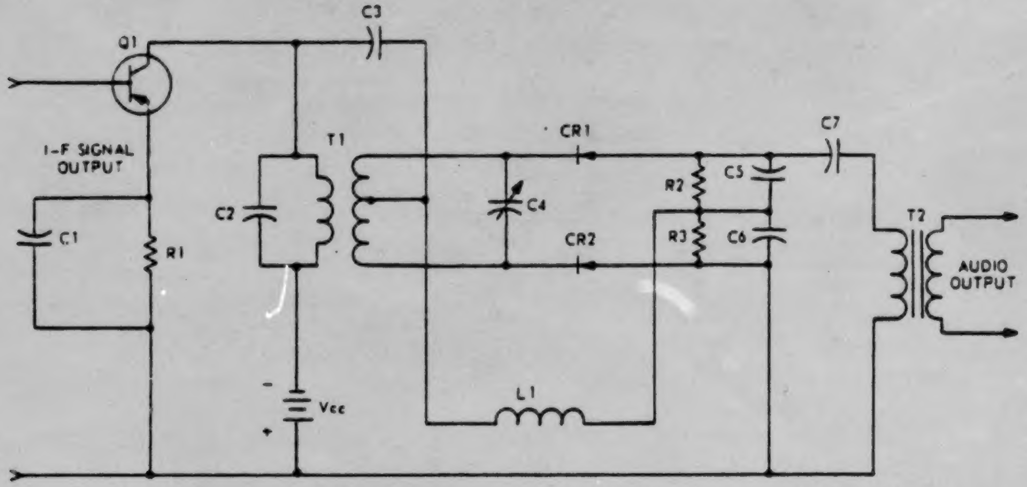


Figure 91. I-f amplifier and discriminator.

and stabilization arrangements are not illustrated. However, the relative transistor d-c potentials required for normal functioning of the oscillator are shown.

13-18. The circuits in parts A and B of figure 89 are similar. In both cases feedback is coupled from the collector to the base by a transformer (tickler coil). The circuit in B is a shunt-fed version of the circuit in A. Since the feedback signal is from collector to base in each case, the necessary feedback signal phase inversion is accomplished by the transformer which, when properly connected, provides a 180° phase shift.

13-19. The circuits in parts C and D are also tickler-coil oscillators. In C, regenerative feedback with zero phase shift is obtained in the tuned collector-to-emitter circuit by the proper connection of the transformer. In D, since the feedback is from collector to base, a 180° phase shift is required. The signal in the untuned collector winding is coupled and inverted in phase to the tuned base winding.

13-20. The circuits in parts E and F are transistorized versions of the Colpitts type electron tube oscillator. In E, the signal from the tuned collector is coupled to the emitter in phase. In F, the signal from the tuned collector is coupled to the base 180° out of phase.

13-21. The circuits in parts G and H are similar to those in E and F except that a split inductance is used to provide the necessary feedback in place of the split capacitance. These are transistorized versions of the Hartley type electron tube oscillator. In each of these circuits, the collector is tuned. Since each coil functions as an autotransformer, feedback in proper phase is accomplished by induction. In G, the feedback signal is coupled from collector to emitter with no phase shift. In H, the feedback signal is coupled from collector to base with a 180° phase shift.

13-22. *AM detector section.* The circuits shown in figure 90 select, rectify, and filter, thereby detecting the amplitude variations of a specific AM signal; in TV the video signal is AM. The selectivity is, of course, accomplished by the tuned tank circuit. The tank is made resonant to the desired center frequency, and it is designed to have a Q that allows the desired sideband frequencies to be accepted. The semiconductor diode rectifies the accepted signal. A p-n junction diode is commonly used, but a point contact diode can be used for low current applications. The diode may be placed in series with an RC filter (fig. 90,A) or in parallel with an RL filter (fig. 90,B). The latter arrangement is more suitable for a current-driven, low input impedance device such as a transistor. This does not mean, however, that the circuit shown in figure 90,A, is not also designed for transistor inputs.

13-23. Diode detectors are simple and will handle relatively large signals. They give high-fidelity detection for signals of sufficient amplitude. For small signals (less than about 1 volt), square-law detection occurs; some detectors are designed to take advantage of this type of detection.

13-24. Two drawbacks of diode detectors are: (1) they provide no power gain, and (2) selectivity is affected by loading. Since a rectifying diode is not an amplifying device, we know there can be no power gain realized. Loading affects selectivity because the input tank "sees" the load.

Consequently, the Q of the tank is lowered when the load increases and increased when the load decreases.

13-25. *FM detector section.* Since we refer to demodulation in an FM receiver of the incoming audio carrier signal as detection, in TV FM detection is also necessary in additon to AM detection. Figure 91 shows a transistorized version of an i-f stage and a discriminator, a circuit used for detecting FM signals. Amplifier Q1 amplifies the i-f signal applied to the discriminator. Resistor R1 is the emitter swamping resistor, and capacitor C1 is an i-f bypass. Capacitor C2 and the primary of transformer T1 form a parallel-resonant circuit for the i-f signal which is coupled through the transformer to the discriminator. Capacitor C3 couples the i-f signal to the secondary of transformer T1 for phase shift comparison. The i-f signal, coupled across capacitor C3, is developed across coil L1. Capacitor C4 and the secondary of transformer T1 form a resonant circuit for the i-f signal coupled through the transformer. The top half of transformer T1 secondary, diode CR1, coil L1, load resistor R2, and filter capacitor C5 form one half of the comparison network. The bottom half of transformer T1 secondary, diode CR2, coil L1, load resistor R3, and filter capacitor C6 form the second half of the comparison network. The audio output of the discriminator circuit is taken from the top of capacitor C5 and the bottom of capacitor C6. The audio output is coupled through capacitor C7 to the primary of transformer T2. The audio signal, coupled through transformer T2, is appled to the following stage.

13-26. The slope detector is also used to detect FM signals by converting the frequency changes of a carrier signal into amplitude changes. The amplitude changes can then be detected by an AM transistor detector. The input and output waveforms of a slope detector and an AM diode detector are shown in figure 92. The i-f signal with frequency deviations is applied to slope detector Q1. The output of slope detector Q1, the i-f signal with amplitude and frequency deviations, is applied to diode detector CR1. The resultant output is an audio signal which is equivalent to the frequency deviations of the i-f input signal.

13-27. The i-f signal coupled through transformer T1 is applied to the base circuit. The resonant circuit, consisting of coil L1 and capacitor C2 (tuned slightly off the carrier frequency), develops a large amount of i-f signal when the frequency deviation is near the resonant frequency. As the frequency diviation of the i-f

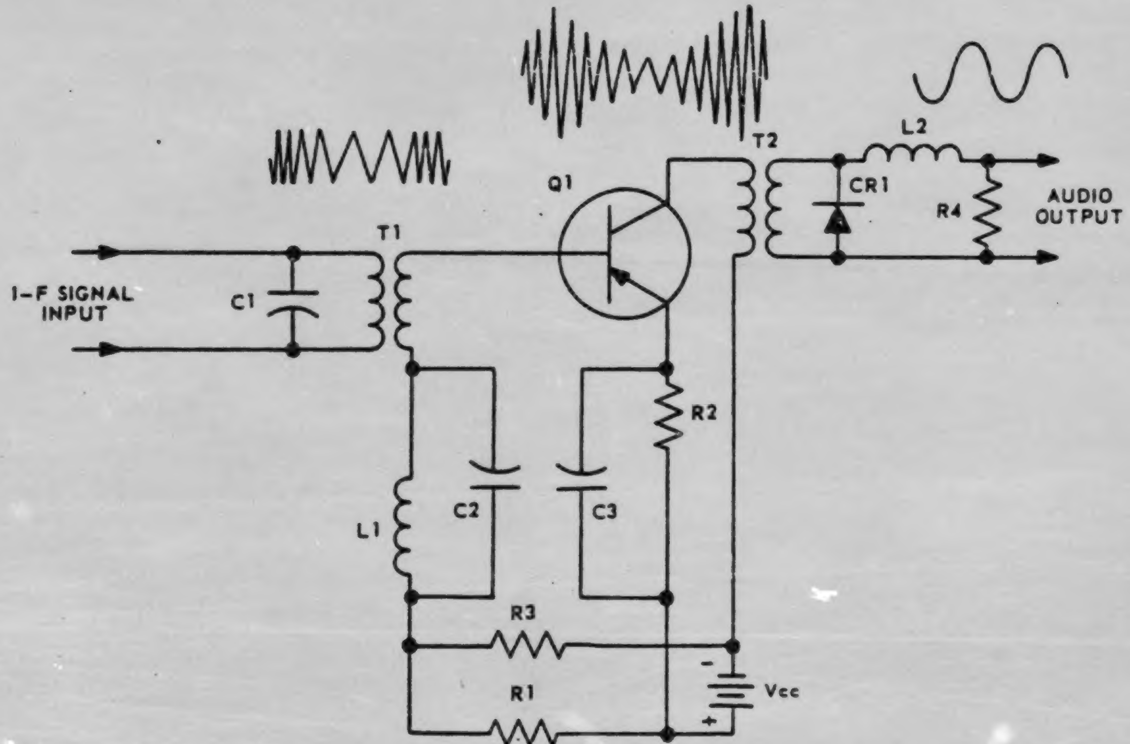


Figure 92. Slope detector and diode detector.

signal becomes lower than the resonant frequency of the resonant circuit, a smaller amount of i-f signal is developed. A large amount of i-f signal added to the bias voltage developed across resistor R1 increases the emitter-base bias and a small amount of i-f signal decreases the emitter-base bias. The emitter-base bias is therefore increasing and decreasing as the frequency of the i-f signal increases and decreases, respectively. Since the bias of slope detector Q1 changes at the frequency deviation rate, the output of the slope detector is an i-f signal that is changing in amplitude and frequency. The i-f signal applied to diode detector CR1 is rectified, filtered by coil L2, and developed across resistor R4. The output of the current output type diode detector is an audio signal.

13-28. **Maintenance.** Maintenance of the TV receiver consists of cleaning and tube replacement (tube type equipment). We use the term "maintenance" as meaning care and upkeep of the TV receiver. However, we can extend our meaning to include the repair of the equipment, which immediately leads to troubleshooting. Troubleshooting a TV set to locate defects is done by a systematic step-by-step analysis. The logical procedure is to:

- Locate the trouble in a particular circuit group or section.
- Isolate the stage or circuit at fault.
- Locate the faulty component.

13-29. To be technically competent in servicing TV receivers, you must be able to understand the correct function and operating principle of each circuit. Your ability to analyze and rapidly diagnose troubles is not developed merely by studing a chapter on troubleshooting. You must realize that success in troubleshooting is a result of understanding the principles of TV receivers, keeping informed on new developments, and learning specific methods of recognizing faults.

13-30. The TV receiver, monochrome or color, can be used to localize its own trouble. You can localize the trouble to one section of the receiver if you analyze the visual and audio indication. Test equipment plus your knowledge of TV principles will enable you to isolate the fault to a particular stage, circuit, or component.

13-31. **Color TV Receivers.** Color TV receivers are different from monochrome receivers in only three sections—color synchronizing, demodulation (chrominance), and matrix. The luminance channel corresponds to the video channel section of the black and white receiver and therefore is new in name only. It should be noted that all sections must be operated under closer tolerances than monochrome receivers, and the technician must follow correct practices when working with and adjusting color receivers.

13-32. The three sections just mentioned as being different in the color receiver were discussed in Volume 1, Chapter 7. At this point, therefore, you should review the referenced section to reinforce your understanding of monochrome and color receiver differences. The color receiver will be more complex due to the additional circuits involved; thus the maintenance will be restricted to precision quality workmanship. You must follow the same logical procedure when troubleshooting because the basic principles of operation are the same.

CHAPTER 5

UHF Equipment

BECAUSE OF co-channel and adjacent-channel broadcasts, the limited number of VHF channels available created a problem. Since only VHF channels 2 through 13 were available, more channels were needed. This need led to the designation of the UHF broadcast channels 14 through 83. In this chapter a comparison of UHF to VHF transmitters, antennas, and receivers will be given. Also, you find material explaining microwave relay applications plus the associated transmitters, antennas, and receivers used to accomplish signal relay.

14. Transmitters

14-1. The transmitters used for TV broadcast and TV relay are of many designs and sizes. The frequency range, the intended operating characteristics, and the manufacturing techniques in use at the time of design will determine many of the physical and electrical characteristics of the final product. Within all of these variables, there are certain principles which will appear in each transmitter no matter how different the techniques employed to obtain them. The transmitter consists basically of an oscillator, a modulator, and an r-f amplifier; it also contains such additional refinements as frequency multipliers and automatic frequency control.

14-2. **Characteristics.** Many similar characteristics are found in VHF equipment which operates in the 54-MHz to 216-MHz frequency range and UHF equipment which operates in the 470-MHz to 890-MHz range. You will also find that the same characteristics are included in microwave relay equipment. Like VHF, UHF radio waves are propagated through the atmosphere and are not effectively returned to the surface of the earth at usable receiving levels. This limits the effective range of TV communication to points on the surface of the earth not far beyond the optical horizon as seen from the transmitting antenna.

14-3. As the frequency is increased through the VHF/UHF range, the radio waves become shorter in physical length and are comparable in size to the component parts of the equipment. This tells us that much consideration must be given to circuit design and component selection. You will recall that the formula for computing wavelength is:

$$\text{Wavelength} = \frac{\text{velocity}}{\text{frequency}}$$

With this formula and a knowledge of the frequencies used, we can compute some component dimensions. The VHF broadcast frequencies were listed in the previous chapter; therefore, to complete your knowledge of the broadcast frequencies used, the UHF channels and respective frequencies are listed as follows:

Channel No.	*Frequency Limits (MHz)*
14	470–476
15	476–482
16	482–488
17	488–494
18	494–500
19	500–506
20	506–512
21	512–518
22	518–524
23	524–530
24	530–536
25	536–542
26	542–548
27	548–554
28	554–560
29	560–566
30	566–572
31	572–578
32	578–584
33	584–590
34	590–596
35	596–602
36	602–608
37	608–614
38	614–620
39	620–626
40	626–632
41	632–638
42	638–644
43	644–650
44	650–656

Channel No.	*Frequency Limits (MHz)*
45	656–662
46	662–668
47	668–674
48	674–680
49	680–686
50	686–692
51	692–698
52	698–704
53	704–710
54	710–716
55	716–722
56	722–728
57	728–734
58	734–740
59	740–746
60	746–752
61	752–758
62	758–764
63	764–770
64	770–776
65	776–782
66	782–788
67	788–794
68	794–800
69	800–806
70	806–812
71	812–818
72	818–824
73	824–830
74	830–836
75	836–842
76	842–848
77	848–854
78	854–860
79	860–866
80	866–872
81	872–878
82	878–884
83	884–890

14-4. Remember also that we will be using additional bands of frequencies for microwave relay purposes. For commercial TV relay use, there are three bands for video use and one additional band for audio relay. The three video bands are:

1990 MHz to 2110 MHz	(2000-MHz band)
6925 MHz to 7050 MHz	(7000-MHz band)
13.025 MHz to 13,200 MHz	(13,000-MHz band)

The additional audio carrier band is 890.5 MHz to 910.5 MHz (900-MHz band). This audio carrier band is not as widely used as are landlines. Otherwise, multiplexing equipment is used and the audio is carried with the video in the primary frequency band. When these bands are used for TV, it is only necessary to use a 6-MHz channel to carry both the video and audio signals.

14-5. **Comparisons.** The UHF transmitter will have the same basic oscillator, multiplier, and amplifier circuits at the lower frequency levels as the VHF transmitter. The differences in component sizes and arrangements of UHF and VHF become evident at the higher frequency power levels. To help you understand the operational characteristics, complexity, and components used, we will study representative power amplifiers.

14-6. *VHF power amplifier.* A modern r-f power amplifier designed for operation in the 54-MHz to 216-MHz frequency range is shown in figure 93. Although this amplifier uses a type 4X150A (see fig. 94) coaxial tetrode tube, the remainder of the circuit is made up of conventional lumped-property components. Referring to the left portion of figure 93, we see that the signal to be amplified is applied to the grid through inductor L5 which matches the input impedance to the grid-circuit impedance. Capacitor C17, resistor R1, and inductor L6 from a loading circuit for the grid with amount of resistive loading being determined by the setting of variable capacitor C17. Inductor L6 balances the stray capacitance of resistor R1. The tube is biased for class C operation by the voltage drop across cathode resistor R6 (lower center of fig. 93) and by the voltage drop caused by the grid current flowing through inductors L5 and L3 and resistors R3 and R2 when the grid is driven positive by the incoming r-f signal. Capacitors C1 and C2 serve as r-f bypasses for resistors R3 and R2. The voltage developed across R2 is applied to the grid meter. The meter reading is an indication of the amount of signal applied to the control grid.

14-7. The cathode current, which is the combined plate and screen-grid current, flows through bias resistor R6 which is bypassed for r-f currents. Resistors R5 and R7 form a voltage-divider network for the cathode meter.

14-8. The screen-grid potential for this stage can be adjusted by changing the setting of resistor R12 (extreme right, fig. 93). Adjustable screen-grid voltage is a refinement which is not found in all r-f amplifier stages. The exact screen potential must be determined from the operating instructions for the stage. Resistor R8 and capacitors C9 and C16 form a decoupling network to prevent any r-f signal from entering the power supply.

14-9. The amplified signal voltage appearing at the plate of the tube is developed across a pi-section network consisting of inductor L1, capacitor C13, and capacitor C14 (upper center, fig. 93). The circuit is tuned to resonance by adjusting C13 and L1. The amount of r-f signal coupled to the antenna through capacitor C15 (upper right, fig. 93) is controlled by the adjustment of capacitor C14. Inductor L2, resistors R9 and R10, and capacitors C10 and C12 form an r-f decoupling network to prevent any of the r-f signal from entering the 750-volt power supply.

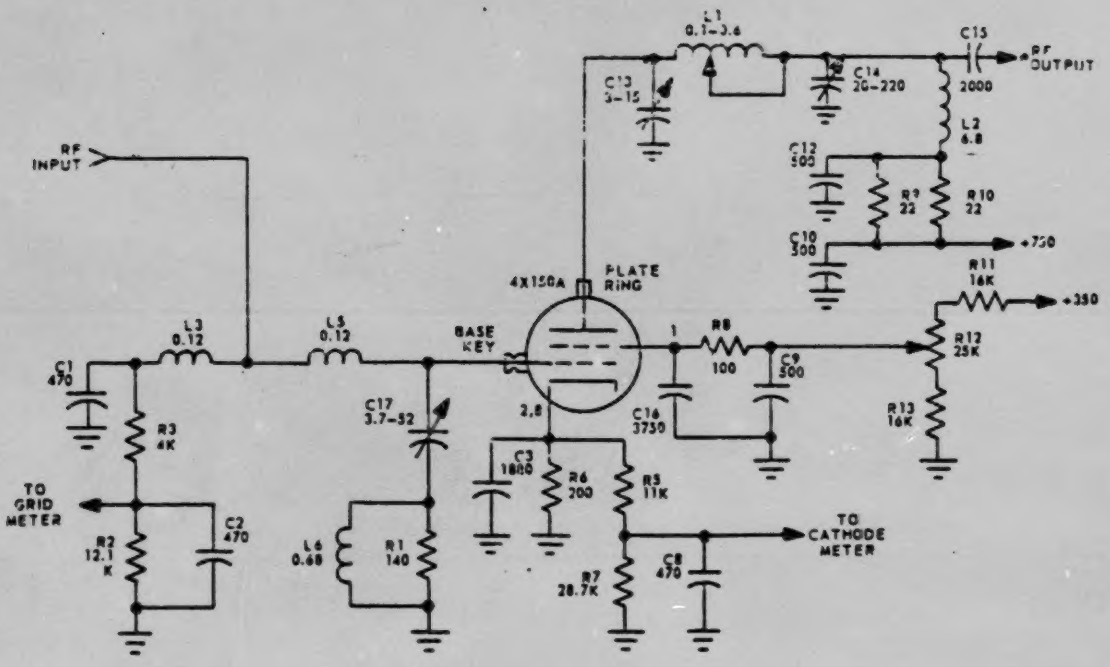

L1
0.1–0.6
C15
RF OUTPUT
C13
3–15
C14
20–220
2000
L2
6.8
C12
500
R9
22
R10
22
C10
500
+750
R11
16K
+350
RF INPUT
4X150A
PLATE RING
BASE KEY
1
R8
100
C9
500
R12
25K
L3
0.12
L5
0.12
C1
470
R3
4K
C17
3.7–32
2.8
C16
3750
R13
16K
C3
1800
R6
200
R5
11K
TO GRID METER
R2
12.1 K
C2
470
L6
0.68
R1
140
TO CATHODE METER
R7
28.7K
C8
470

Figure 93. VHF power amplifier circuit.

14-10. *UHF power amplifier*. A coaxial cavity type r-f power amplifier designed for operation in the 470-MHz to 890-MHz range is shown in figure 95. Not shown in this drawing is the mechanical linkage used to adjust the tuning of the cavities.

14-11. This amplifier is an excellent example of the use of distributed properties in an operat-

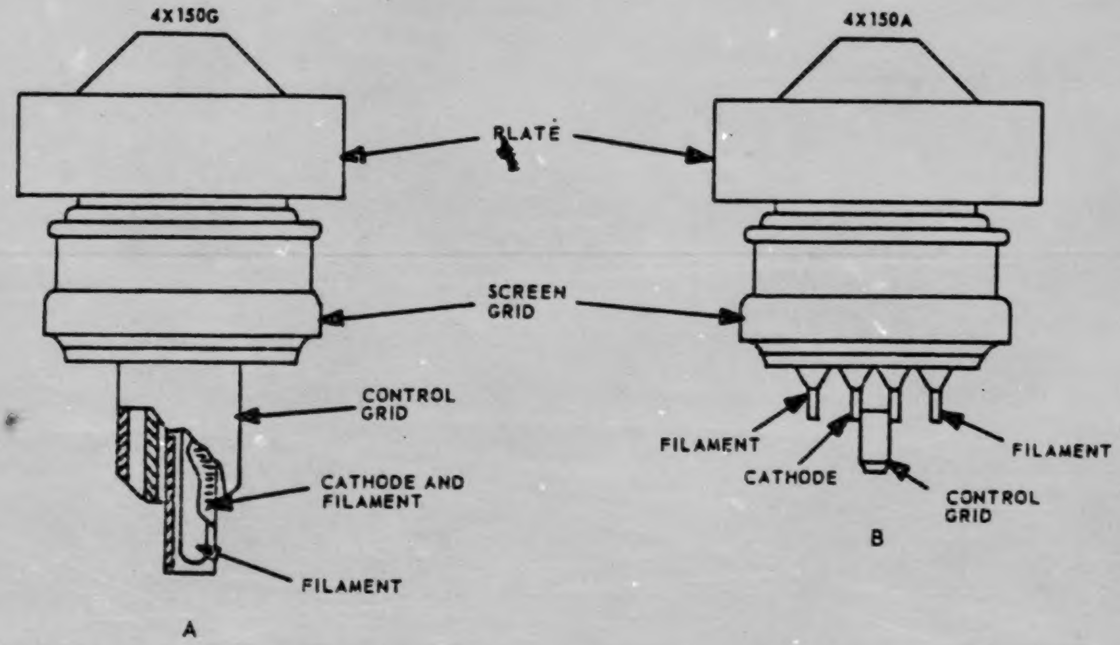
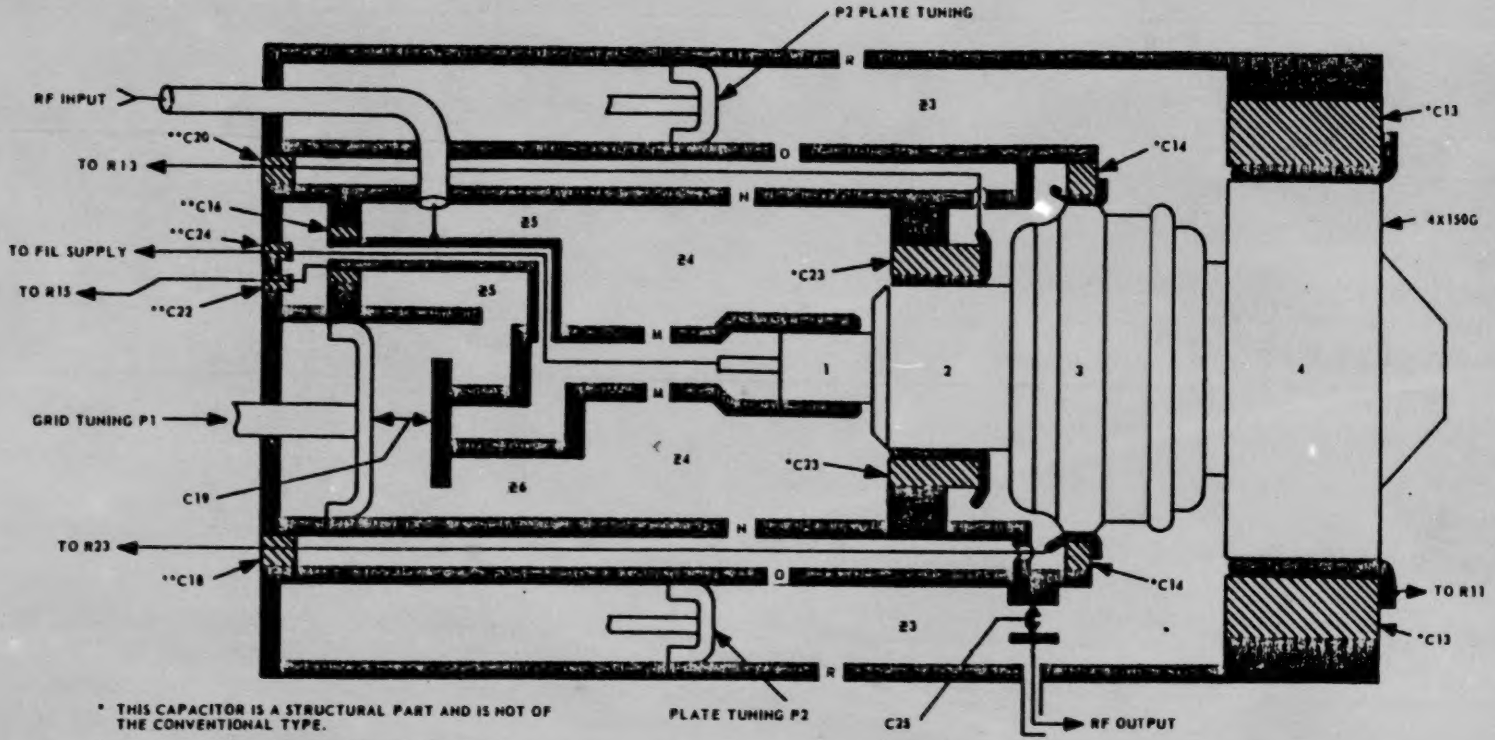

4X150G
4X150A
PLATE
SCREEN GRID
CONTROL GRID
CATHODE AND FILAMENT
FILAMENT
A
FILAMENT
CATHODE
FILAMENT
CONTROL GRID
B

Figure 94. Coaxial tetrodes.


P2 PLATE TUNING
RF INPUT
**C20
TO R13
**C16
**C24
TO FIL SUPPLY
TO R15
**C22
GRID TUNING P1
C19
TO R23
**C18
R
O
N
Z3
Z5
Z4
Z5
Z6
Z4
Z3
1
2
3
4
*C13
*C14
4X150G
*C23
*C23
*C14
TO R11
*C13
PLATE TUNING P2
C25
RF OUTPUT

* THIS CAPACITOR IS A STRUCTURAL PART AND IS NOT OF THE CONVENTIONAL TYPE.

** THIS CAPACITOR IS OF THE FEED THROUGH TYPE.

Z1, Z2, Z3, AND Z4 ARE TUNED CONCENTRIC CAVITIES.

4X150G CONNECTIONS
1 – CATHODE
2 – CONTROL GRID
3 – SCREEN GRID
4 – PLATE

Figure 95. Cutaway view of coaxial cavity type UHF amplifier.

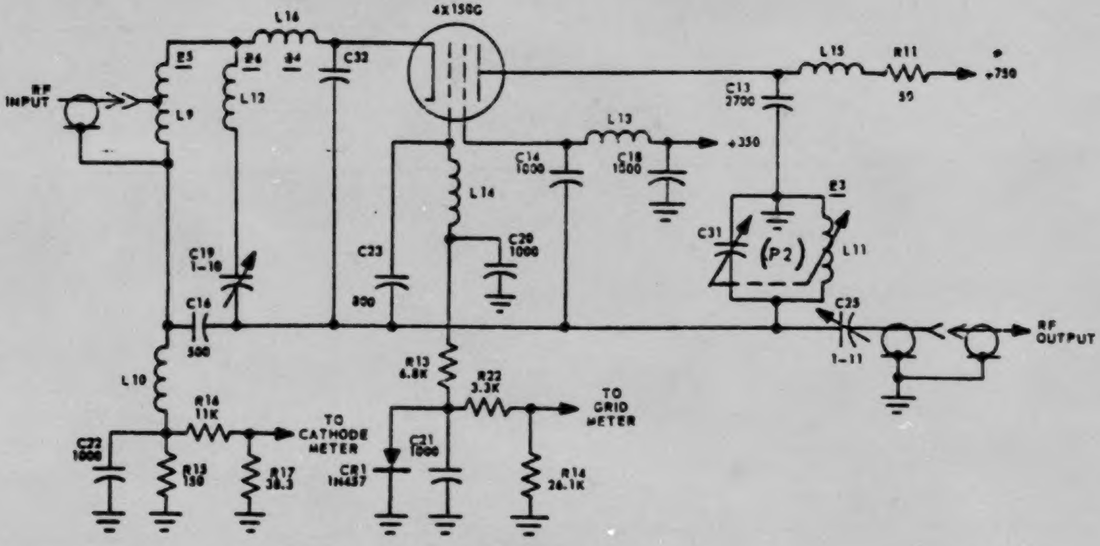


Figure 96. UHF power amplifier circuit.

ing circuit. Plate coupling capacitor C13 (extreme lower right, fig. 95), screen-grid decoupling capacitor C14, and grid decoupling capacitor C23 are all distributed-property capacitances. The capacitance in each case is formed by the metal ring connected to that tube element, the supporting dielectric, and the wall of the cavity supporting the dielectric. The insulating material, besides serving as the dielectric of the respective capacitors and as part of the tube support, prevents the high voltage on the plate and screen-grid elements from being shorted to ground because the cavity structure is at d-c ground potential.

14-12. There are four coaxial cavities in this amplifier. Grid cavity Z4 is formed by rod M and the inner surface of cyclinder N. Input cavity Z5 is formed by the smaller branch of rod M and the associated cavity walls. Tuning cavity Z6 is formed by the larger branch of rod M and the surrounding cavity walls and is tuned by plunger P1 (extreme left, fig. 95). Plate cavity Z3 (lower portion of fig. 95) is formed by the outer surface of middle cylinder O, tuning plunger P2, and outer cyclinder R.

14-13. The amplifier input circuit consists of three coaxial cavities of a different characteristic impedance; in the upper left portion of figure 96, we see these cavities represented as L9, L12, and the combination of L16 and stray capacitance C32. Coaxial line Z5 is short circuited at one end and the input power is fed into a tap on this line. Line Z6, consisting of inductance L12 in series with grid capacitor C19, tunes the input to the operating frequency. These two lines are joined in parallel to the cathode-grid structure of the coaxial tetrode by means of Z4 (L16 and C32). This circuit may be looked upon as a three-quarter waveline in which variable capacitance loading (C19) has been added so as to reduce the physical length of the line. One end of line Z5 is at r-f ground and is connected through bypass capacitors C16 and C23 to the control grid and through capacitor C14 (middle portion of fig. 96) to the screen grid; thus, the control and screen grids are held at r-f ground potential and the circuit functions as a grounded-grid amplifier. The other end of input line Z5 is connected through line Z4 to the cathode and causes the cathode voltage to vary at an r-f rate with respect to the grid. When the grid voltage decreases, capacitor C23 discharges slightly through a length of wire, represented as L14, and through resistors R13, R22, and R14. The r-f plate current is coupled to plate cavity Z3 (extreme right, fig. 96) through blocking capacitor C13. Cavity Z3 (inductance L11 and capacitor C31) is tuned to the same frequency as the input circuit by means of shorting plunger P2 which changes the physical length of the cavity to correspond to one-quarter wavelength at the operating frequency. The voltage across cavity Z3 is coupled to the output circuit through capacitor C25.

14-14. The d-c cathode circuit is formed by L16, L9, and L10. The r-f energy is contained on the top side of L10 (the lead inductance) and is thus isolated from the d-c circuit. Cathode bias is developed across resistor R15 (lower left, fig. 96) which is bypassed by capacitor C22. Capacitor C16 prevents the d-c cathode voltage from being shorted to ground through cavity Z3. A voltage divider, consisting of resistors R16 and R17, is connected across the cathode bias resistor. The voltage across resistor R17 is proportional to the total tube current and is applied to the cathode meter.

14-15. When the cathode becomes more negative than the control grid, grid current flows in pulses which are smoothed out by capacitor C23. The average d-c grid current flows through a length of wire, represented by r-f choke L14, and through resistors R13, R22, and R14, which are bypassed by capacitors C20 and C21. The voltage across R14 is roughly proportional to the amount of drive to the cathode and is supplied to the grid meter which provides an indication of the amount of excitation applied to the amplifier.

14-16. The d-c screen-grid circuit is isolated from the r-f circuit by the inductance of a length of shielded wire, L13. Capacitor C18 provides additional decoupling to prevent r-f from entering the power supply. Inductance L15 (upper right, fig. 96), a length of shielded wire, isolates the d-c power supply from the r-f plate circuit. Resistor R11 provides additional decoupling for the +750-volt power supply.

14-17. The circuits shown in figures 93 and 96 indicate the similarities of VHF and UHF circuits, while figure 95 gives us an idea of the physical differences, since we know the VHF uses conventional lumped-property components as compared to the UHF distributed properties of the amplifier structure.

14-18. **UHF Relay (Microwave).** The Air Force makes wide use of two wideband transmission systems used to relay communications. They are the microwave and tropospheric scatter relay systems and both can be used to relay TV. Microwave relay, however, is the primary system used with TV. A number of models of microwave equipment are in use throughout the Air Force. Some of this equipment is of military design and some is of commercial design.

14-19. Although the design of microwave relay equipment varies, all the equipment is similar in basic design. Some of these similarities are as follows:

- Klystrons. Klystrons are used extensively for generating the microwave r-f signal (at frequencies above 6000 MHz) in the transmitter, and they are used as local oscillators in microwave receivers.
- Waveguides. Waveguides are used for transmission lines in many microwave systems, especially those operating at frequencies higher than 3000 MHz.
- Antennas. Most microwave systems use highly directional paraboloid reflector antennas, or paraboloid reflector and plane reflector antennas in combination.
- Microwave receivers. Most microwave receivers will be similar in design; i.e., they require a large number of i-f amplifiers and the same type of discriminator.

14-20. *Basic microwave system.* A two-way microwave system consists of two complete microwave terminals, both of which will have capabilities for transmitting and receiving microwave signals. Normally, microwave terminals are separated by a distance seldom exceeding 30 to 55 miles. If a greater distance between microwave terminals is involved, repeater stations become necessary. Repeater stations are two terminals connected back to back.

14-21. A basic microwave system, as shown in figure 97, includes a microwave transmitter, a directional transmitting antenna system, a directional receiving antenna system, and a microwave receiver. The main parts of the system in figure 97 are designated A through H.

14-22. Point A shows the microwave transmitter, B transmission line, and C and D show the microwave transmit antenna system at the west terminal. Point E shows the plane reflector at the east microwave terminal. The plane reflector at the receiving terminal is aimed at the transmitting station's plane reflector and directs the microwave beam downward toward the paraboloid reflector. The paraboloid reflector (point F) directs the beam to a particular focal point—the waveguide aperture. Thus, the microwave energy is directed into the waveguide, as shown by point G. Point H shows the microwave receiver. The receiver contains circuits for increasing the signal-to-noise ratio; this increases the signal level for subsequent detection by a discriminator. Microwave receivers use conventional superheterodyne receiver principles. A reflex klystron is used as a local oscillator; its signal is combined with the incoming signal in a diode type mixer arrangement to produce an i-f signal.

14-23. *Velocity modulation.* The klystron belongs to a class of tubes known as velocity-modulated tubes. In a conventional vacuum tube, an electron beam is modulated by varying the number of electrons. In a velocity-modulated tube, the electron beam is modulated by varying the electron velocities.

14-24. The behavior of a velocity-modulated electron beam can be shown on a graph known as

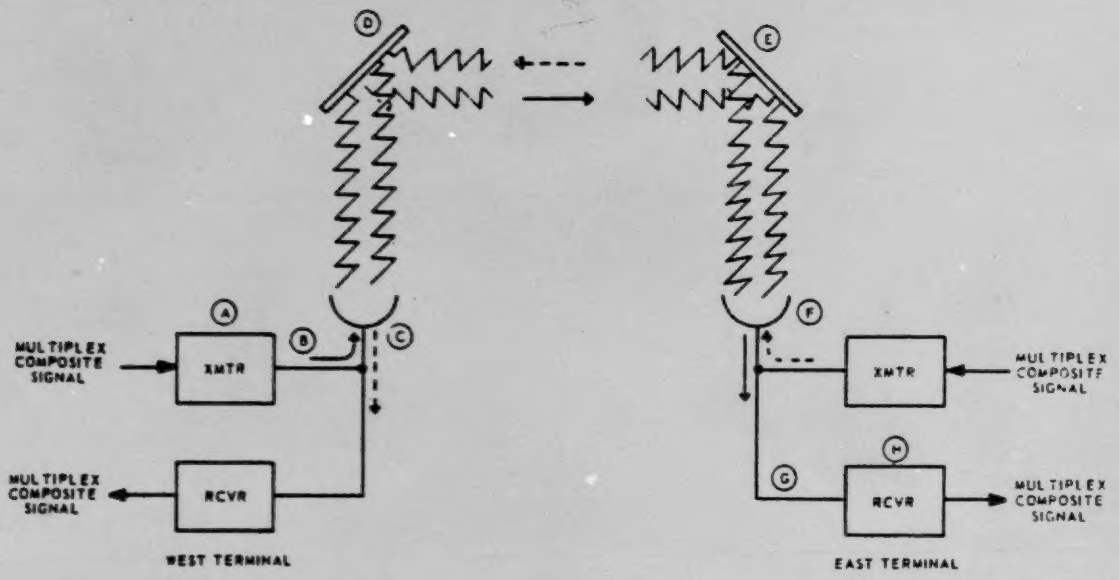

D
E
A
B
C
F
G
H
MULTIPLEX COMPOSITE SIGNAL
XMTR
MULTIPLEX COMPOSITE SIGNAL
RCVR
WEST TERMINAL
XMTR
MULTIPLEX COMPOSITE SIGNAL
RCVR
MULTIPLEX COMPOSITE SIGNAL
EAST TERMINAL

Figure 97. Basic microwave system.

an Applegate diagram (fig. 98,C). In figure 98,A, the distance traveled by an electron is shown as a function of time. Figure 98,B, shows similar plots for electrons that leave the given point at intervals after the zero time. Suppose now that the beam is velocity modulated. As shown in figure 98,C, some electrons will travel faster than others. The plots for these electrons are more nearly vertical than the plots for the slower ones (the slower plots being more nearly horizontal). Figure 98,C, shows the points where bunching occurs—that is, where the faster electrons overtake those traveling at normal velocities and the slower electrons fall back to those traveling at normal velocities.

14-25. Figure 99 shows an example of a reflex klystron. It consists of a heater, cathode, resonator cavity with two grids, drift tube, and a repeller plate. The cavity, as well as the body of the tube, is usually (not always) operated at ground potential. The cathode is operated at a negative potential so that the first cavity grid serves as an accelerator. The second cavity grid, on the side away from the cathode, velocity-modulates the electron beam. The repeller plate is operated at a potential slightly more negative than the cathode, and it serves to turn the electrons back toward the cavity.

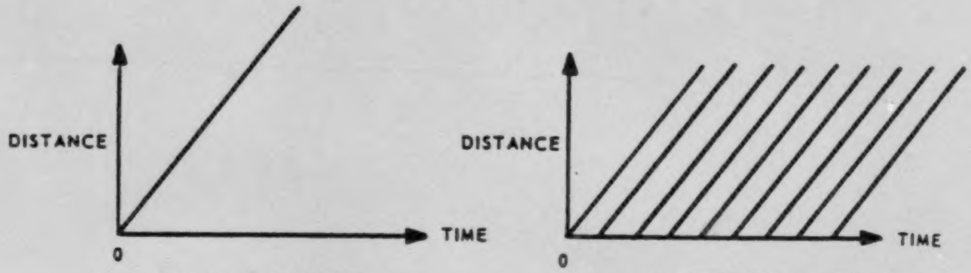
14-26. Operation of the reflex klystron depends upon the proper relation between the cathode voltage, repeller voltage, and cavity tuning. Note the arrangement of the electrodes and the voltages involved for operation of the reflex velocity-modulated tube shown in figure 100. Electrons are emitted by an indirectly heated cathode. These electrons are attracted by the cavity grids. The grids are more positive than the cathode by the amount of voltage E_a. The electrons emitted from the cathode travel toward the cavity grids at a velocity determined mainly by voltage E_a.

14-27. Most of the electrons pass through the cavity grids and continue on toward the repeller plate. After passing the cavity grids they come to the drift tube. Since the repeller plate is negative with respect to the cathode, the electrical field in the drift tube opposes the electrons' motion. The strength of the electrical field is determined by voltage E_r. Thus, the electrons stop, reverse direction, and pass back to the cavity grids. They are collected by either the shell of the tube or by the cavity grids which are connected to the tube shell.

14-28. When the electrons return to the cavity grids, the voltage across the cavity grids again acts upon the electrons. Since they are now traveling in the opposite direction, they will be decelerated if they return when the grid voltage is positive and accelerated if they arrive when the grid voltage is negative.

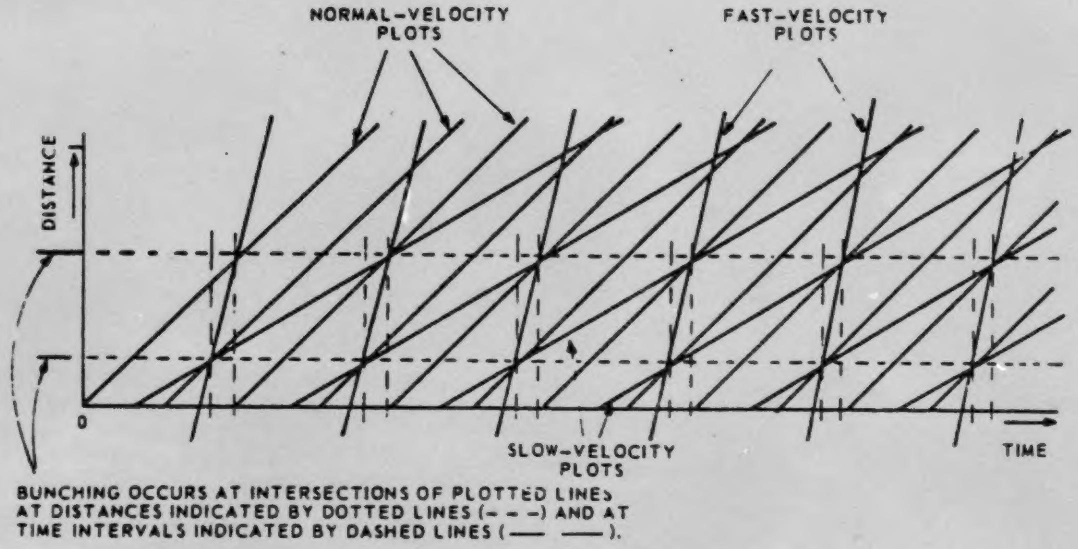
14-29. Reflex klystrons are capable of being tuned across a band of approximately 300 MHz. The resonant cavity of a klystron can be mechanically tuned to a desired frequency in several ways. Three tuning methods are shown in figure 101. Figure 101,A, shows how the resonant frequency point of the cavity may be changed by use of a capacitive tuning slug. Figure 101,B, shows how the resonant frequency point may be changed by the use of an inductive tuning slug. Both of these tuning methods are somewhat equivalent to conventional tank circuit tuning, where the resonant frequency point is changed by a variable capacitor or inductor. Whether or not the resonant cavity tuning slug is inductive or capacitive depends upon the position of the slug in relation to the electric and magnetic fields within the cavity. Figure 101.C. shows a third technique for tuning the resonant cavity. This tuning method involves physically changing the dimensions of the cavity. With this tuning technique, the cavity is designed so that it may be compressed or expanded. The cavity is squeezed when pressure is applied. This causes the upper cavity grid to move closer to the lower cavity grid. This change in grid spacing increases the capacitance and lowers the resonant frequency of the cavity. All of these mechanical tuning methods are considered to be coarse frequency adjustments.

14-30. A slight change in repeller voltage is sufficient to change the klystron frequency several megahertz or more. Thus, it is a method for fine tuning of a klystron. When the repeller is made more negative in relation to the cavity grids, the repelling force on the electrons is increased. Therefore, an electron passing through the cavity grids on its way from the cathode will return sooner and the frequency of oscillation will be raised. There is, of course, a limit to the amount of frequency change that can be obtained by changing the repeller voltage. The frequency will change approximately 1 MHz for a 1-volt



A. SINGLE ELECTRON

B. NUMBER OF ELECTRONS



BUNCHING OCCURS AT INTERSECTIONS OF PLOTTED LINES AT DISTANCES INDICATED BY DOTTED LINES (– – –) AND AT TIME INTERVALS INDICATED BY DASHED LINES (—— ——).

C. APPLEGATE DIAGRAM

Figure 98. Applegate diagram.

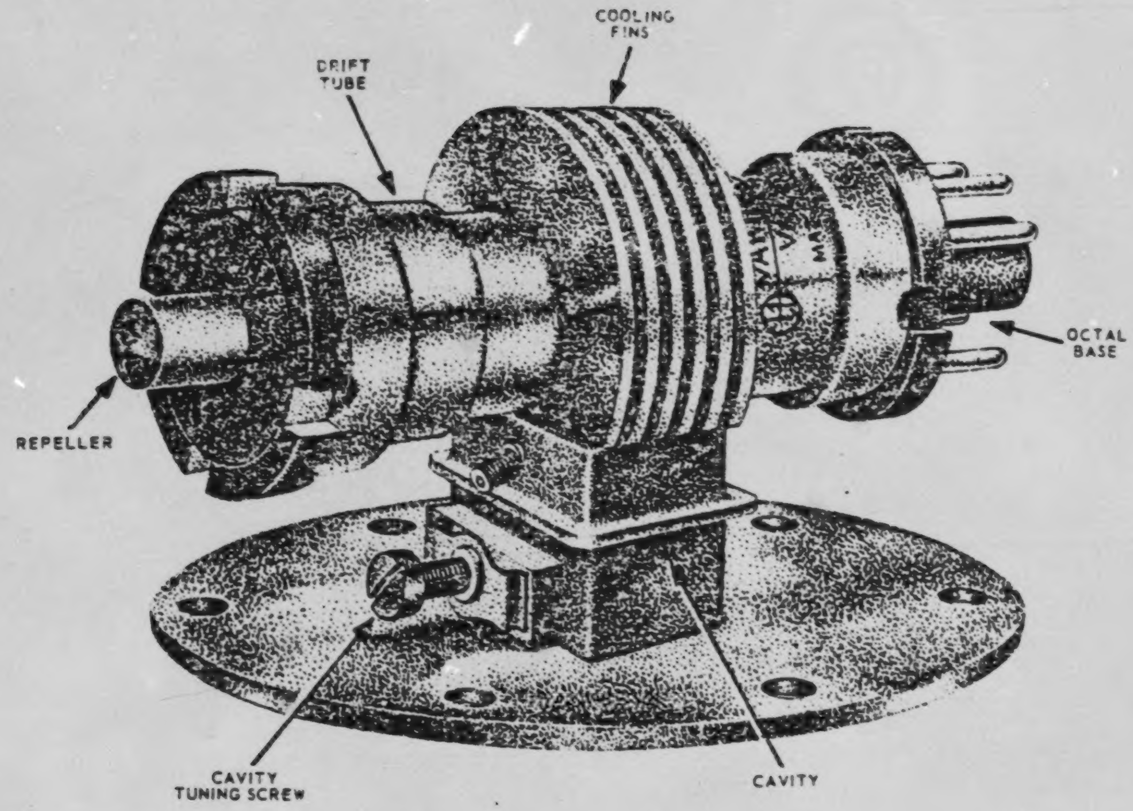

COOLING FINS
DRIFT TUBE
OCTAL BASE
REPELLER
CAVITY TUNING SCREW
CAVITY

Figure 99. Reflex klystron.

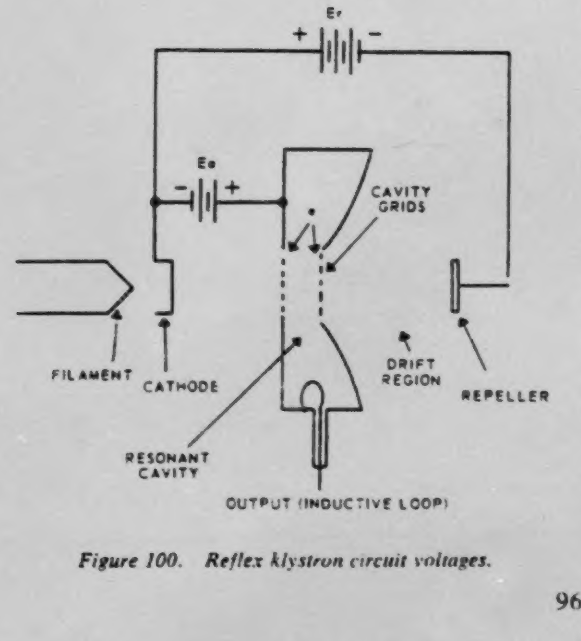

Er
+
−
Eo
−
+
CAVITY GRIDS
FILAMENT
CATHODE
DRIFT REGION
REPELLER
RESONANT CAVITY
OUTPUT (INDUCTIVE LOOP)

Figure 100. Reflex klystron circuit voltages.

change in the repeller voltage. In general, by changing the repeller voltage and retuning the cavity, a reflex klystron can be tuned over a range of about ±5 percent from the center of its operating band. When the repeller voltage is changed, it can be frequency-modulated over a range of about ±0.5 percent of its operating frequency. Remember, however, that the frequency modulation is accompanied by some amplitude modulation when the frequency shift is accomplished by variation in the repeller voltage.

14-31. Frequency modulation of the klystron signal is accomplished by feeding the modulating voltage to the repeller of the klystron. The modulating voltage frequency modulates the internal klystron signal by making the repeller voltage more or less negative. The amplitude of the modulating voltage determines the amount of klystron frequency deviation, and the frequency of the modulating voltage determines the rate of klystron frequency deviation. For many klystrons a 1-volt change in repeller voltage produces a 1-MHz change in klystron frequency. The amount of repeller voltage change required to produce a 1-MHz change in klystron frequency is com-

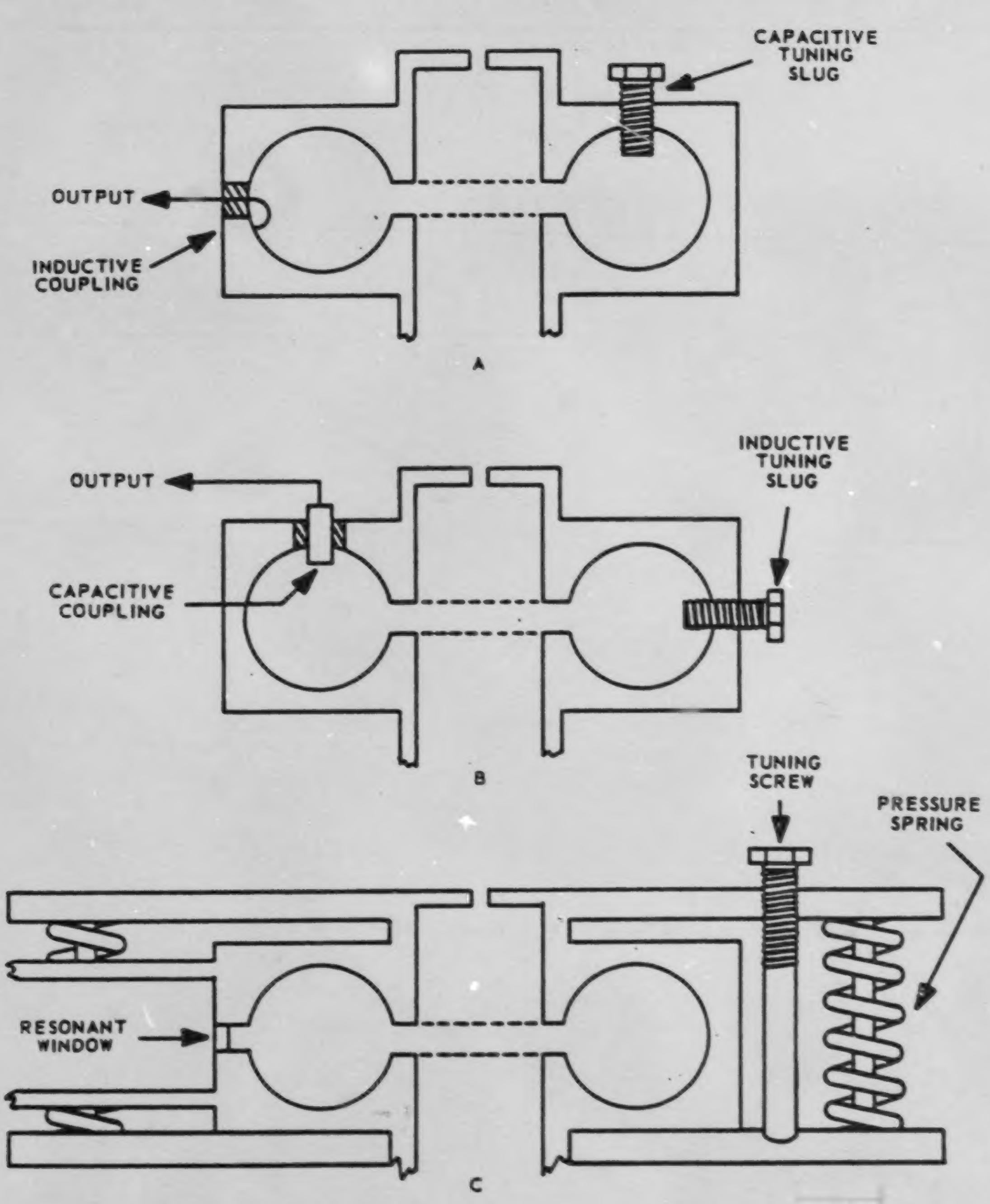

CAPACITIVE TUNING SLUG
OUTPUT
INDUCTIVE COUPLING
A
INDUCTIVE TUNING SLUG
OUTPUT
CAPACITIVE COUPLING
B
TUNING SCREW
PRESSURE SPRING
RESONANT WINDOW
C

Figure 101. Reflex klystron cavity tuning methods.

monly referred to as the klystron modulation sensitivity. Thus, a modulation sensitivity of 1v/MHz implies that the repeller voltage must change 1 volt to change the frequency 1 MHz. You may encounter slight differences between individual klystron modulation sensitivities.

14-32. The multiplexed aural and visual signal must be sufficient in voltage amplitude to be applied to the kystron repeller. In some cases the signal will consist of a visual signal only and the aural signal is relayed by another method. When the multiplexed signal is used, the necessary signal strength is achieved in the input combining and amplification circuits.

14-33. **Transmitter Maintenance.** After equipment is installed and in an operational mode for a period of time with all initial discrepancies corrected, you still have the task of maintaining performance. To maintain UHF equipment in a satisfactory condition requires a slightly different approach from the way low-frequency equipment is maintained. With UHF, especially microwave equipment, it is not enough to "dip" the plate and "max" the grid. Also you do not just peak-up the tuning of a stage as in equipment with narrow-band tuning. With wide-bandpass equipment, you must be extremely careful of any voltage change as this could change the operating bandpass and resonant frequency. Any dirt, lint, or other particles carried into a tuning cavity by the cooling system could change its capacitance and cause a frequency shift. Along this same line, with high voltages and close tolerances, arcing can be a problem with foreign particles in cavity areas. Cleanliness, precision adjustments, stable power, and avoiding unnecessary touchups are some of the things to remember when maintaining UHF and microwave equipment.

15. UHF Antennas

15-1. As stated in Section 11, the UHF band 470–890 MHz, is assigned to television channels 14 through 83 by FCC. Assignments of higher frequencies are made for portable, mobile, and point-to-point TV service. The frequency assignment for a particular piece of equipment is made by FCC in accordance with the locality and the peculiar needs of the equipment.

15-2. Television stations receiving allocations in the higher frequency ranges fall into the following categories: (1) remote-pickup stations, (2) studio-to-transmitter link stations, (3) intercity relay stations, (4) broadcast translator stations, and (5) broadcast booster stations. A remote-pickup station transmits program material and related communications from a remote site to the primary TV broadcast station. A studio-to-transmitter link station transmits program and related communications from a fixed-base remote station to the primary TV broadcast transmitter. Intercity relay stations retransmit the program and related communications between two TV stations. A broadcast translator station retransmits the initial TV program on a different frequency carrier. A broadcast booster station retransmits the signal of a primary broadcast station by amplifying and reradiating the incoming signal on the same frequency carrier.

15-3. **UHF Transmission and Propagation.** Propagation characteristics for UHF and higher frequencies are less favorable than for VHF. Atmospheric absorption of signal energy is increased. Likewise, shadow effect is more severe because the higher frequency wave passing over an obstacle does not disperse itself in back of the obstacle (shadowed area) as does a lower frequency wave. The transmission range of UHF and higher frequencies is limited to short distances.

15-4. In TV microwave links, transmission is usually required between a transmitter and only one receiving station. Therefore, it is desirable that both the transmitting and receiving antennas be highly directional. The general requirements for receiving and transmitting antennas are that they have small energy losses and that they be efficient as receptors and radiators.

15-5. **UHF Receiving Antennas.** Many types and designs of UHF receiving antennas are available on the commercial market. Our discussion will be limited to some of the more popular ones—i.e., corner reflector, V-type, bow-tie, and parabolic reflector.

15-6. *Corner reflector.* The corner reflector gives good results under adverse conditions, is relatively directional, and has excellent gain over a major portion of the UHF spectrum. It consists of a half-wave radiator set in the plane of a line bisecting the corner angle formed by two flat metal reflector sheets. Construction of a typical corner reflector is illustrated in figure 102.A. For horizontal polarization, the radiator and reflector

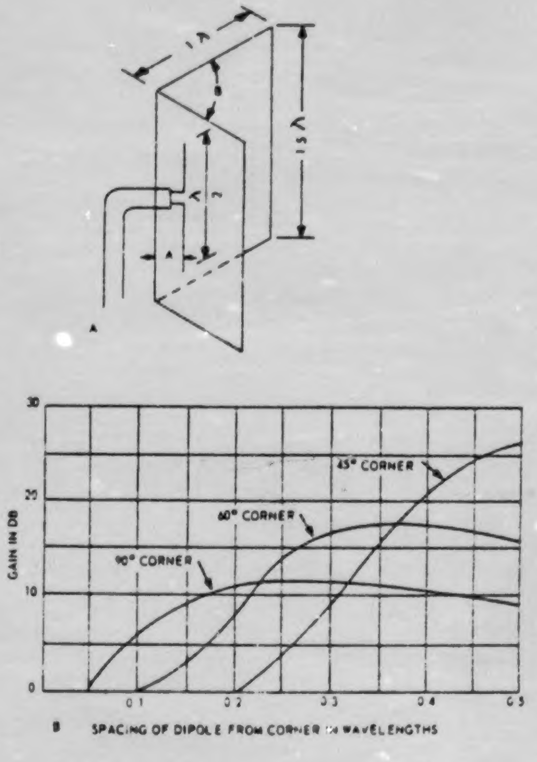


Figure 102. Corner reflector antenna.

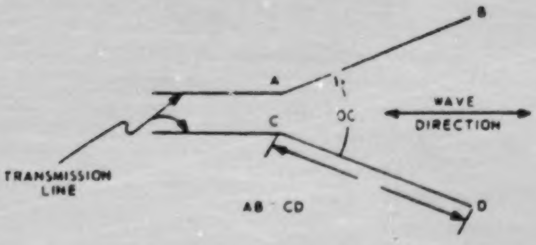


Figure 103. Basic V-antenna.

are mounted in the horizontal plane. This mounting arrangement results in a very narrow vertical radiation pattern with maximum signal radiated in line with the bisector of the corner angle. The directivity in the horizontal plane is approximately the same as for any half-wave radiator having a single-rod type of reflector behind it.

15-7. Both gain and radiation resistance of the antenna are affected by the reflector corner angle B, the spacing between the radiator and the corner A, and the size of the reflector. Figure 102.B, shows the gain (expressed as a power ratio) between the dipole with a reflector and a basic dipole antenna for corner reflector antennas having different corner angles. In some applications, the driven element is made in the form of a folded dipole to increase input impedance. The reflector often consists of a screen with openings spaced approximately one-tenth wavelength apart.

15-8. *V-type antenna.* The V-type antenna is another version of the dipole antenna. Each of the quarter-wave elements of the dipole is slanted forward to form a V-shape. (Fig. 103 illustrates the construction of a basic V-antenna.) The V is formed at such an angle that the main lobes reinforce along the line bisecting the V to make a very effective bidirectional antenna.

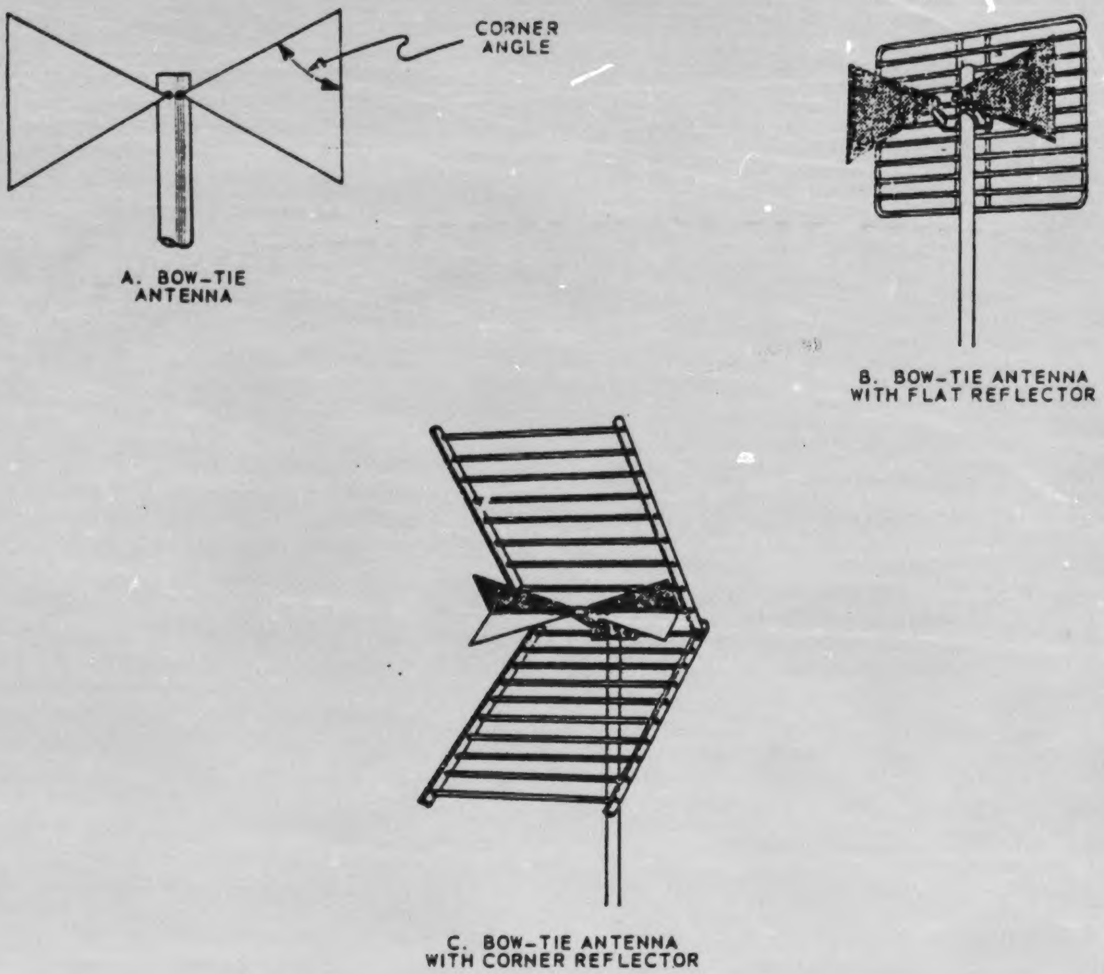
15-9. The V-antenna has a broad bandwidth capable of covering the VHF as well as the UHF stations that serve an area. As the frequency of the received signal increases, the antenna ceases to be a ½-wavelength structure. Each leg gradually becomes a wavelength relative to the frequency of the arriving signal. For example, if each of the two legs of a V-antenna is cut for ¼ wavelength at channel 2 (54–60 MHz), they become ¾ wavelengths at 180 MHz, almost 2½ wavelengths at 600 MHz, and approximately 3½ wavelengths at 840 MHz. The gain of this type of antenna is dependent upon its leg lengths and upon the angle which the two legs make with each other. Since gain is almost directly proportional to the leg length, it would seem advisable to make each leg as long as possible. However, there are structural limitations. With excessive extension of leg length, the antenna becomes unwieldy and readily breaks when exposed to wind, ice, or snow. This problem is partially overcome by using antenna elements of sufficient diameter (⅜ to ½ inch) to provide additional strength. Design variations include adding or stacking V's to increase gain and directivity.

15-10. *Bow-tie antenna.* The bow-tie antenna (sometimes called fanned dipole) is still another variation of the dipole. In order to achieve the broadband characteristics necessary to receive all signals within the TV UHF band, triangular sheets of metal are used instead of rods (see fig. 104, A). The array is normally designed with a corner angle of 70° to achieve an input impedance of approximately 300 ohms. The radiation pattern of a bow-tie antenna is a figure eight; however, if a screen is placed behind the dipole (as shown in fig. 104.B), the field becomes unidirectional.

15-11. The gain is only slightly greater than that of a rod dipole; therefore, these units provide satisfactory reception in strong signal areas where there are relatively few ghost signals. Bow-tie antennas, however, can be stacked two and four high to provide increased gain and better discrimination against ground-reflected signals. Notice that the reflector in figure 104.B, is a wire screen instead of the rods usually used at VHF. Screens are as effective as solid metallic reflectors, provided the openings are no larger than 0.2 wavelength at the highest operating frequency. Reflector dimensions are not critical, but the edges should extend for a short distance beyond the dipole elements. As shown in figure 104.C, the corner reflector is also used with the bow-tie antenna.

15-12. *Parabolic reflector.* Parabolic reflectors are generally used in TV microwave relay systems. They are used in both transmitting and receiving antenna systems. The principles of operation of antennas designed for operation in the super-high-frequency range are the same as for the lower frequency antennas. However, because of the small physical size of the radiating elements, full advantage can be taken of directive arrangements for efficient line-of-sight operation.

15-13. Focusing microwave energy is a relatively easy task, because the radiation properties of microwave frequencies approach those of light waves. Figure 105 shows how this focusing of energy is accomplished in many microwave relay systems. Energy is radiated from the aperture antennas into a paraboloidal-shaped reflector (parabolic reflector). This reflector concentrates the microwave energy into a tight beam. As shown, a plane reflector intercepts the beam of energy. The plane reflector is tilted at an angle



A. BOW-TIE ANTENNA

B. BOW-TIE ANTENNA WITH FLAT REFLECTOR

C. BOW-TIE ANTENNA WITH CORNER REFLECTOR

Figure 104. . Bow-tie antenna.

sufficient to direct the beam toward the distant station. The angle of tilt depends upon the positioning of the parabolic reflector, plane reflector. and distant station.

15-14. In most microwave antenna systems, the parabolic reflector and the aperture antenna assembly are constructed as one unit. The waveguide is fed through the rear at the center of the reflector. The aperture antennas are positioned at a point above the reflector.

15-15. Figure 106 illustrates the beaming action of a microwave parabolic reflector. Note that all parts of a wavefront leaving point A arrive at line BC simultaneously. Thus, the parabolic reflector forms the energy from the waveguide into a beam in the direction of the plane reflector which, in turn, reflects the microwave beam toward the distant station. The receiving characteristics of a parabolic reflector are also such that r-f energy striking the surface of a parabolic reflector forms a well-defined focal point. Hence, energy received from the distant station is directed into the waveguide at point A (the aperture antenna).

15-16. **UHF Transmitting Antennas.** In comparison with a VHF system, the UHF antenna system must generate a higher signal gain in order to service a given area. The complicated feeder system and stacked element array methods used with VHF systems would introduce losses if further advanced to accommodate the higher gains necessary in UHF systems. The higher frequency and shorter wavelengths of the UHF signals require a new approach.

15-17. The loop antenna in its basic form is simply a coil of wire used to radiate energy. The shape of the radiation pattern varies with variations in the diameter of the loop. If the diameter is less than 0.585 λ, the field of maximum radiation is in the plane of the loop. Radiation at right angles to the plane of the loop is nil.

15-18. The slotted loop (slotted ring) antenna, a modification of the basic loop antenna, is an effective high-band VHF and UHF transmitting antenna. It consists of a series of slotted rings mounted on a channel, as shown in figure 107. The rings are lenticular in cross section with the long axis in the plane of the rings. This configuration results in an antenna structure that has a minimum resistance to wind forces. Two parallel rods are mounted to the rings, one along each side of the open portion. This arrangement forms a continous slot and acts as a balanced transmission line. Figure 108 shows a section of this type of antenna mounted on a supporting mast. A basic slotted ring antenna is a bay consisting of two radiating elements (called half bays) arranged one above the other and fed with a single rigid coaxial transmission line.

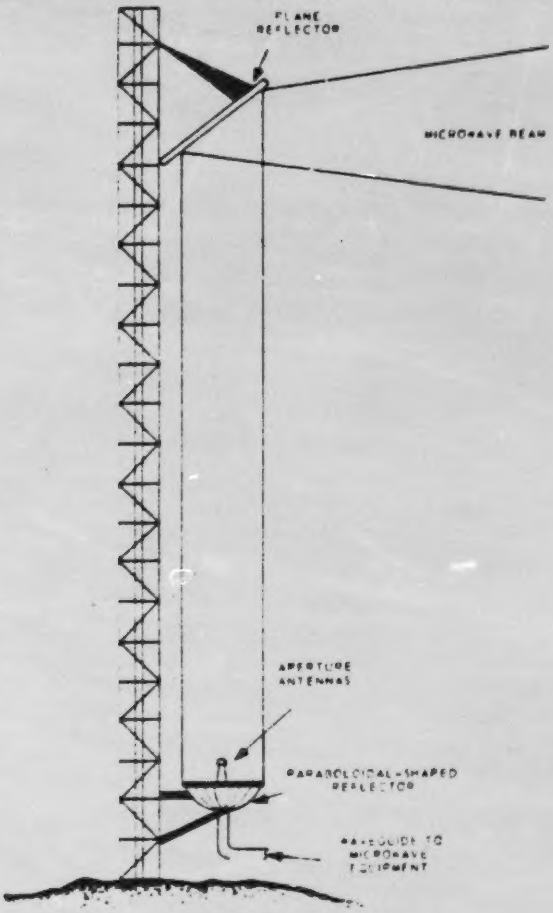

PLANE REFLECTOR
MICROWAVE BEAM
APERTURE ANTENNAS
PARABOLOIDAL-SHAPED REFLECTOR
WAVEGUIDE TO MICROWAVE EQUIPMENT

Figure 105. Microwave antenna system.

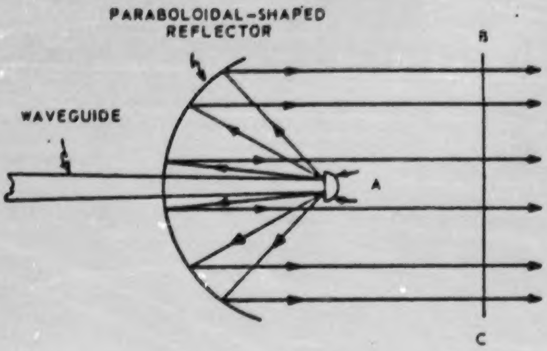


Figure 106. Paraboloidal-shaped reflector.

15-19. We can best understand the operation of the slotted ring antenna by considering it as a balanced transmission line shunted by a number of loops, or rings. The phase velocity at which a very-high-frequency wave is propagated along the transmission line can be substantially varied by properly arranging the separation and cross-sectional area of the rings. Figure 109 shows a loaded transmission line short-circuited at one end and fed with r-f energy at the other. Standing waves having an apparent wavelength are set up along the line. When the number of rings along the balanced transmission line is approximately 12 per free-space wavelength and the diameter of each ring is approximately 0.14 of the free-space wavelength, the apparent wavelength

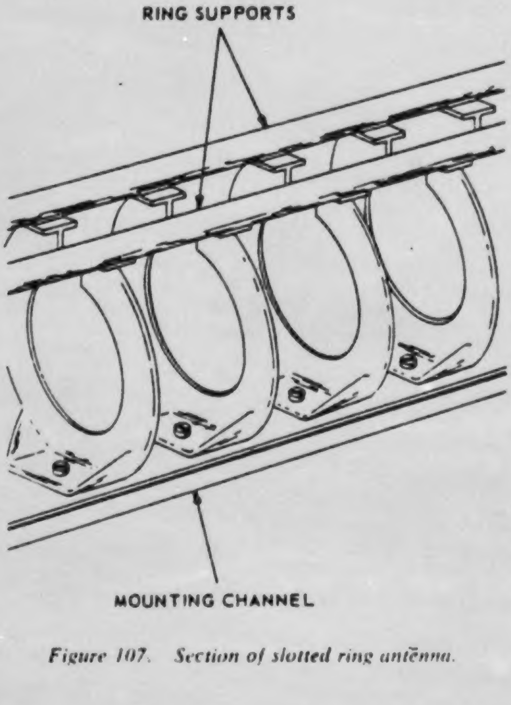


Figure 107. Section of slotted ring antenna.

will be about twice that of the free-space wavelength.

15-20. When the same arrangement is short circuited at both ends and fed at the center through a length of transmission line (as shown in fig. 110), a wave propagates from the center feed point toward each of the short-circuited ends. The reflected wave from the ends sets up a standing wave, and the difference of potential between the conductors of the antenna and the balanced transmission line is distributed approximately as shown. The phase of this potential difference is essentially constant over the entire length of line. The difference of potential exist-

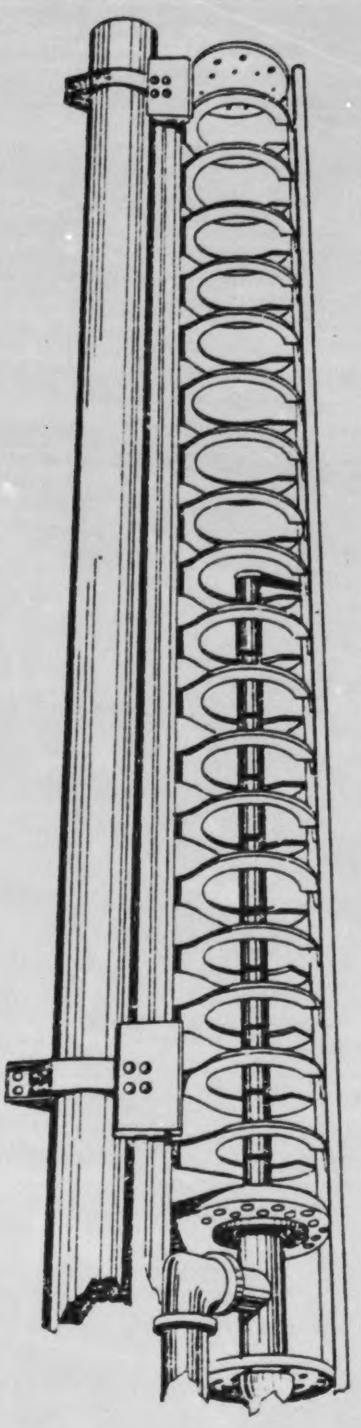


Figure 108. Slotted ring antenna mounted on pole.

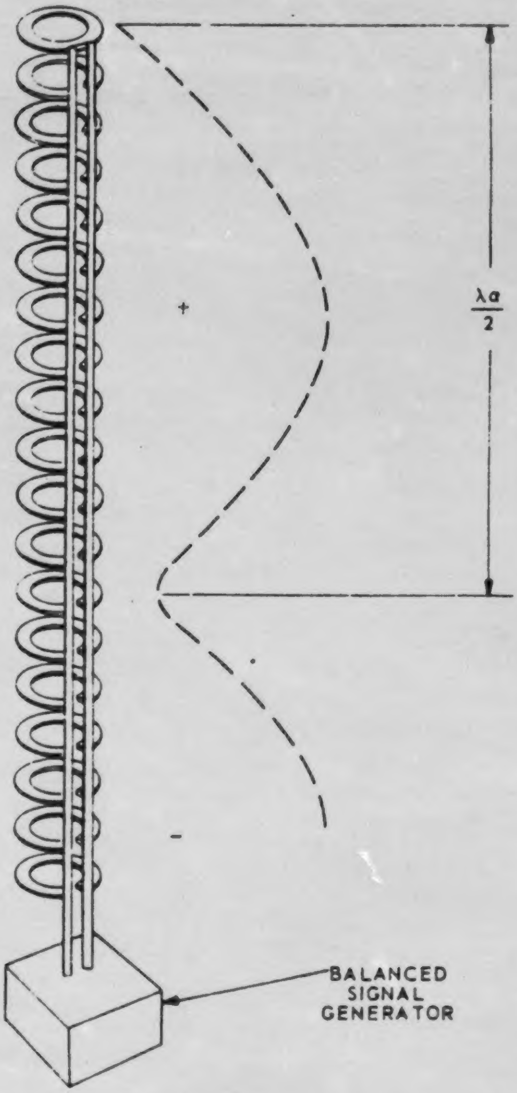


Figure 109. Balanced transmission line loaded with shunt rings

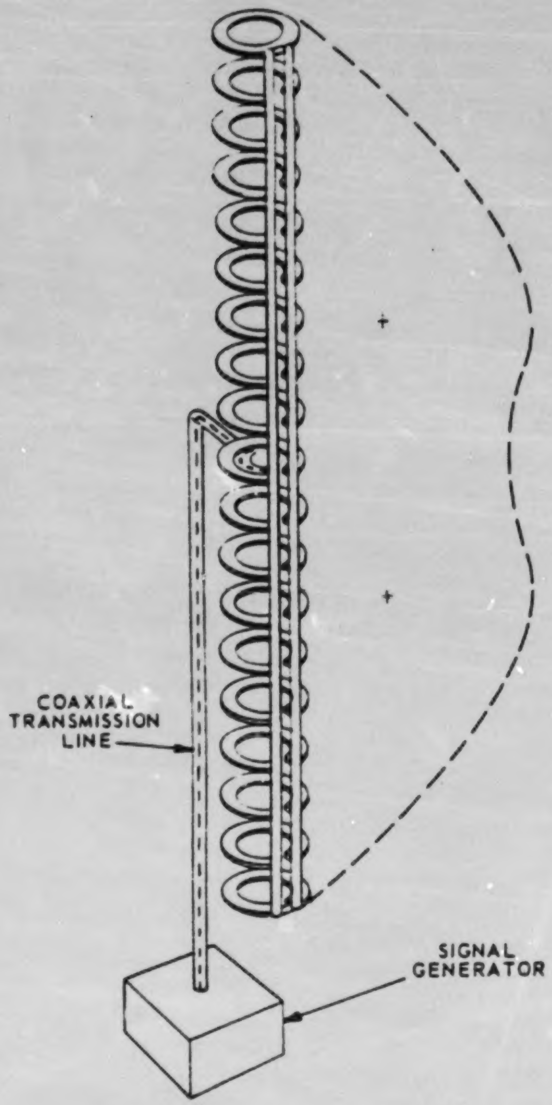


Figure 110. Unbalanced transmission line loaded with shunt rings.

ing between the balanced conductors causes circumferential currents to flow in the shunting rings.

15-21. Gain is proportional to the number of bays used. Each transmitting bay is approximately 3.4 wavelengths at the operating frequency and has an average power gain of approximately 4. As many as five bays may be stacked one above the other. High-gain antenna configurations are practical for use at the high-band VHF and UHF channels because of the short physical antenna lengths.

15-22. The slotted ring antenna is capable of handling high input power. Rigid coaxial transmission lines running to each bay permit the use of approximately 35 kw in the high VHF band.

15-23. The impedance of the slotted ring antenna is a nominal 50 ohms. Since the antenna is fed by a single rigid coaxial transmission line having a nominal impedance of 50 ohms, no impedance matching problems exist.

15-24. The horizontal radiation pattern of this antenna is essentially circular. Directional horizontal radiation patterns are achieved by adding pattern-shaping members to the basic antenna. A common method is to connect two beam-shaping members to each alternate active ring. The rings to which these members are attached direct a substantial portion of the antenna current into the beam-shaping elements.

15-25. **UHF and VHF Antennas Compared.** Although UHF antennas actually can include any one of the VHF antennas previously discussed, the UHF antenna will be considerably smaller in physical dimension. It has a lower length-to-diameter ratio; hence, it has a lower Q and wider bandwidth response than the VHF antenna. Stacked arrays and other complex systems have much less wind resistance, less weight, and are not as massive. The UHF antenna is less subject to interference from the surrounding area than is its VHF counterpart. Even when tin roofs, rain pipes, or other metal objects which might influence antenna performance are nearby, the UHF antenna is farther away from these influences in terms of actual wavelengths. Some VHF antennas can be converted to VHF/UHF antennas by modifying their mounting arrangements. Among those that can be made suitable for both VHF and UHF reception are the VHF conical antenna and the VHF V-type antenna.

15-26. Impedance matching at the antenna and, more importantly, at the receiver requires more careful attention in UHF installations. Mismatching at the receiver results in energy being reflected back along the line with resultant standing waves. Attenuation characteristics of a line may be increased substantially over its normal rating when standing waves are present. In strong signal locations, the additional loss may not be serious; however, in moderate and weak signal areas, it can mean the difference between usable and unusable pictures.

15-27. **Waveguide.** A special type of transmission line, the waveguide, is used when greater transmission efficiency is required that can be obtained from coaxial lines. Electromagnetic fields transfer the energy in a waveguide without the use of a center conductor. The waveguide may be considered a hollow pipe and may be round, square, rectangular, or elliptical. Waveguides have certain advantages over the transmission lines. Radiation losses are very small in a waveguide because the fields are contained wholly within the guide. Since a waveguide has a large surface area and does not have a center conductor, the copper losses are less than those in other types of lines. Since the absence of a center conductor also eliminates the need for a solid dielectric support, dielectric losses are less. The power-handling capability of a waveguide is greater than that of a coaxial line having an equal size because the distance between the conductors of the waveguide is greater. Waveguides are also simplier to construct than coaxial lines.

15-28. Waveguides are used in UHF TV transmission systems when greater power-handling capacity and lower signal attenuation is desired. Waveguides may also be employed in the microwave relay system. Two of the sizes of typical rectangular waveguides are 5¾ by 11½ inches (650- to 1000-MHz range) and 7½ by 15 inches (450- to 750-MHz range). The waveguides are formed using copper-clad steel or aluminum. The installation of a waveguide system for UHF is much the same as with coaxial lines and the same precautions should be followed. Transition or coupling devices must be used if the system requires a change from waveguide to coaxial line or from coaxial line to waveguide along the transmission route.

16. UHF Receivers

16-1. In the preceding section, only the VHF TV channels (2 through 13) r-f tuners using the superheterodyne principle were discussed. In many areas it is possible to receive ultra-high-frequency (UHF) TV channels. In the past, TV receivers were manufactured with combined VHF/UHF tuners or with the VHF tuner only. Separate UHF tuners are available for VHF sets originally manufactured for VHF only.

16-2. **UHF Conversion.** There are several methods of heterodyning the UHF signal down to the i-f signal range. One method, direct heterodyning, shown in figure 111.A, employs a UHF local oscillator whose frequency is equal to the total of the desired i-f and the UHF incoming signal. If a UHF signal is being received on channel 31 (572–578 MHz), the UHF oscillator will be set on 619 MHz to heterodyne with the video carrier frequency of 573.25 MHz. The difference frequency will be the i-f video carrier frequency, 45.75 MHz.

16-3. Another method of UHF heterodyning, shown in figure 111.B, uses an external converter that can be connected to a standard TV receiver having only a VHF tuner. This method uses the double superheterodyne principle whereby the UHF signal is heterodyned two times before it is reduced to the i-f range of the TV receiver. In the example illustrated in figure 111.B, UHF channel 21 is to be received. The UHF local oscillator will be set on 430 MHz for channel 21 (512–518 MHz) reception. Heterodyning the UHF oscillator frequency with the video carrier frequency (513.25 MHz) of channel 21 will produce an 83.25-MHz signal in the output of the external converter. The frequency 83.25 MHz is the video carrier frequency of channel 6. Injecting the output of the external converter into the antenna input terminals of the VHF TV receiver and with the channel selector on channel 6, the VHF local oscillator will be set to 129 MHz. The second heterodyning step, mixing 129 MHz with 83.25 MHz, will result in a difference frequency of 45.75 MHz. With the external converter set on channel 21 and the VHF receiver set on channel 6, the picture on channel 21 will be produced on the screen of the VHF receiver. An additional i-f amplifier in the output of the external converter is usually used to step up the first heterodyned i-f signal into the VHF receiver.

16-4. A third method of UHF heterodyning, as shown in figure 111.C, uses a harmonic generator (frequency multiplier) to produce the desired UHF oscillator frequency. The harmonic generator usually consists of a crystal circuit whose output is selective to the desired harmonic frequency range (in this case, the third harmonic). No UHF local oscillator stage is needed because an output is taken from the VHF local oscillator (139.75 MHz) and applied to the harmonic generator. The output of the harmonic generator (three times 139.75 MHz) is mixed with the incoming UHF signal to produce the desired i-f signal.

16-5. The direct heterodyning system, as shown in figure 111.A, is usually used with receivers that contain a combination VHF/UHF tuner. The external converter method is used with TV receivers that have only the VHF tuner. The harmonic-crystal mixing method is most often used with receivers in which the tuner design provides plug-in channel strips, as with turret type tuners.

16-6. **Maintenance.** Receiver maintenance for UHF receivers will be increased by the addition of one tube and associated circuit. One very important difference is that the tuning section of a UHF tuner contains some very delicate tabs. These tabs are adjusted to obtain the correct capacitance for proper tracking of the tuner. For this reason it is a good idea to avoid inserting anything into this tuning section, because even a strong blast of compressed air can damage or detune it. Also, rough handling, moisture, ex-

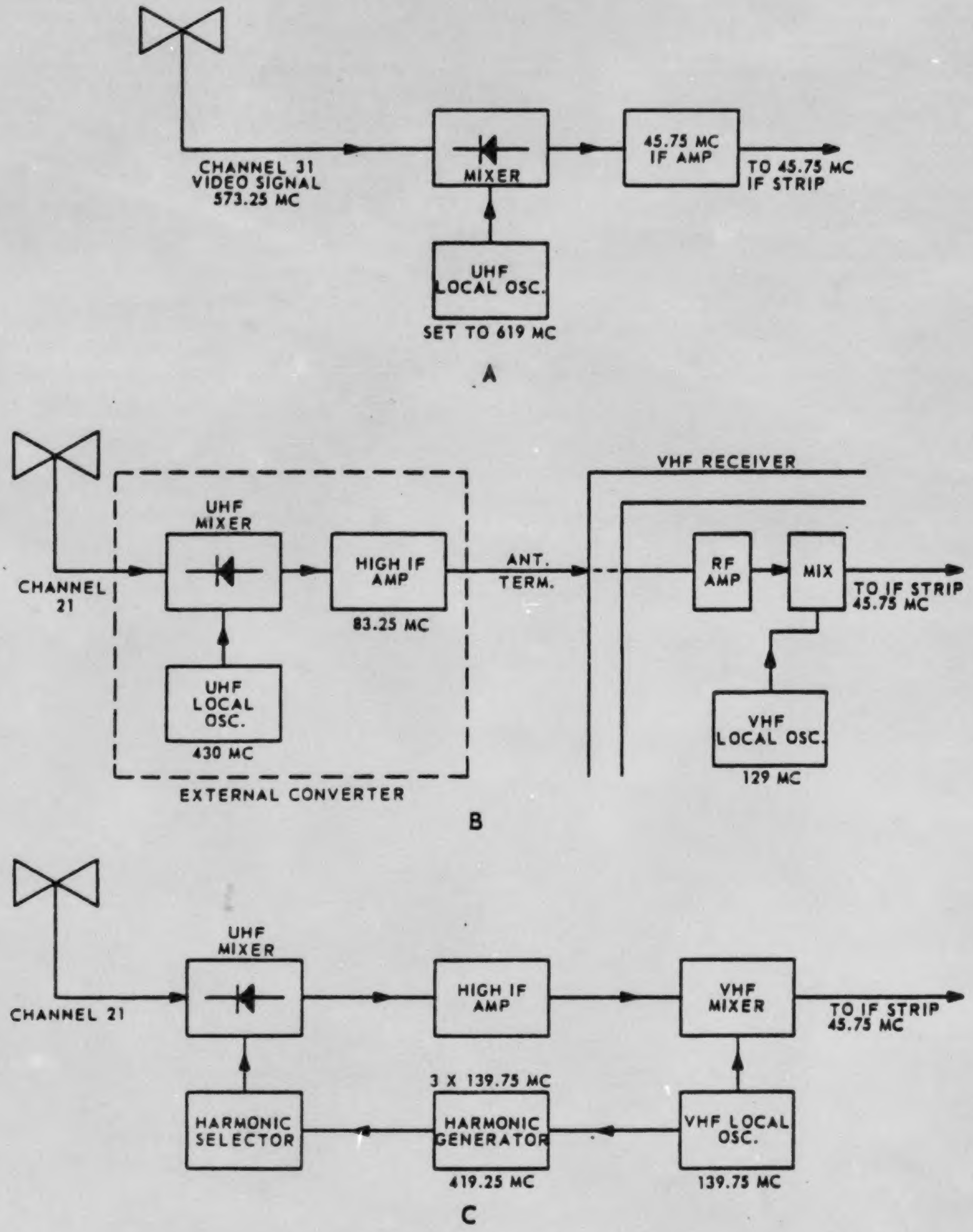

CHANNEL 31
VIDEO SIGNAL
573.25 MC
MIXER
45.75 MC
IF AMP
TO 45.75 MC
IF STRIP
UHF
LOCAL OSC.
SET TO 619 MC
A
UHF
MIXER
HIGH IF
AMP
83.25 MC
CHANNEL
21
UHF
LOCAL
OSC.
430 MC
EXTERNAL CONVERTER
ANT.
TERM.
VHF RECEIVER
RF
AMP
MIX
TO IF STRIP
45.75 MC
VHF
LOCAL OSC.
129 MC
B
UHF
MIXER
CHANNEL 21
HIGH IF
AMP
VHF
MIXER
TO IF STRIP
45.75 MC
3 X 139.75 MC
HARMONIC
SELECTOR
HARMONIC
GENERATOR
419.25 MC
VHF LOCAL
OSC.
139.75 MC
C

Figure 111. Methods of UHF conversion.

tremes of heat or cold, etc., should be avoided. Here also, as stated previously, precision components require precision maintenance. This is especially true of the microwave receiver which must maintain a broad frequency response with the same amount of gain.

16-7. **Microwave Receiver.** The microwave receivers must be capable of receiving weak signals (sometimes as low as −100 dbw). At VHF frequencies it is possible to increase receiver sensitivity by the use of r-f amplifiers. Thus far, amplification of low-level microwave signals has not been practical, except by the use of the parametric amplifier. Microwave receivers, therefore, do not provide amplifications at the received signal frequency. Basically, microwave receivers are FM superheterodyne receivers with sufficient stages of i-f amplification to boost the first detector (mixer) output signal to the desired level. In these receivers the noise generated within the input circuits (first detector and first two i-f stages) is the factor which limits the receiver's signal-to-noise ratio. Normally, a signal-to-noise ratio of 15 db is considered satisfactory for reliable reception. Figure 112 shows a typical modern microwave receiver. Note that this receiver bears a resemblance to an ordinary low-frequency FM receiver except that r-f amplifier stages are not used in the microwave receiver.

16-8. Basically, the microwave receiver operates as follows: The microwave energy is received by the antenna system, radiated down the waveguide to the receive bandpass filter, passed through the filter, and fed to a mixer stage. A local oscillator klystron, operating at a frequency approximately 70 MHz removed from the received signal frequency, is also fed into the mixer stage. The mixer stage produces a number of frequencies at its output. The difference frequency is selected, amplified by a number of i-f amplifiers, and fed to one or more limiter stages. The limiter stages clip the noise from the FM i-f signal. The i-f signal is detected by a discriminator stage. The output of the discriminator consists of the original baseband signal. This signal is then fed to a number of baseband amplifier stages. (Baseband amplifiers are sometimes referred to as video amplifiers or as dropout amplifiers.) The amplified signal is then distributed to the multiplex equipment and to any other appropriate equipment. A portion of the signal at the output of the discriminator is fed to frequency correction circuits. These circuits are used to keep the local oscillator klystron tracking 70 MHz (or the i-f frequency) removed from the frequency of the incoming microwave signal.

16-9. As already mentioned, the microwave receiver uses a klystron oscillator to produce a frequency to mix with incoming r-f. Since this is a different tube from those ordinarily used in receivers, we can assume that probably the UHF frequency receivers will also use specialized tubes. In the UHF receiver the input signal is weak and needs amplification for mixing and detecting.

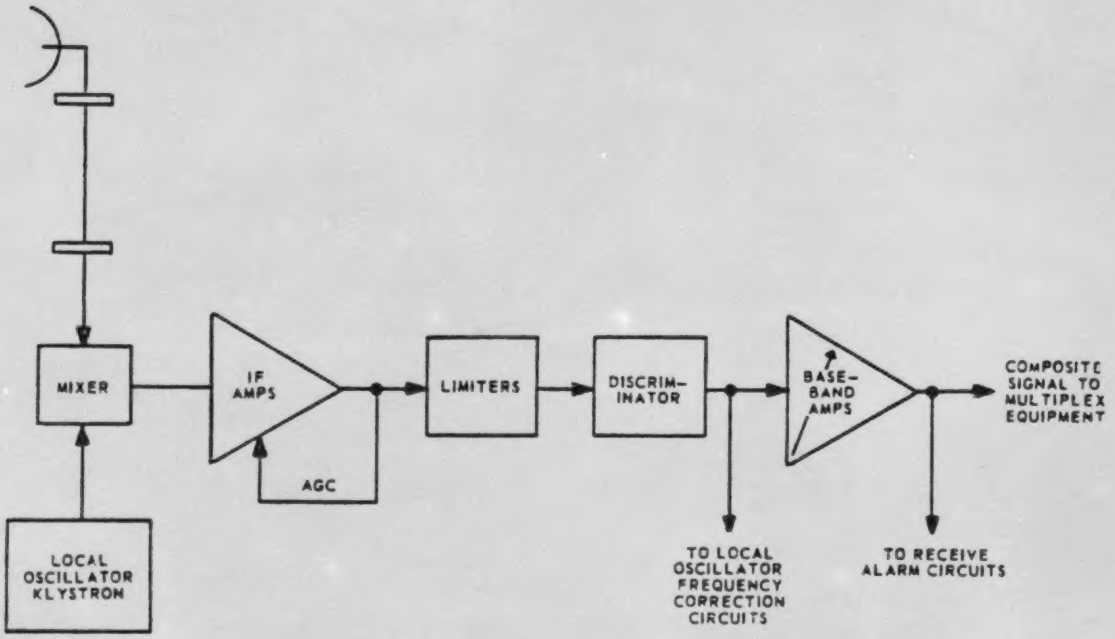

MIXER
IF AMPS
AGC
LIMITERS
DISCRIM-INATOR
BASE-BAND AMPS
COMPOSITE SIGNAL TO MULTIPLEX EQUIPMENT
LOCAL OSCILLATOR KLYSTRON
TO LOCAL OSCILLATOR FREQUENCY CORRECTION CIRCUITS
TO RECEIVE ALARM CIRCUITS

Figure 112. Microwave receiver block diagram.

However, in most UHF tuners there will be a mixing of the input signal and local oscillator with subsequent amplification of the i-f signal. Again, the reason for not amplifying the input r-f is that there will be too much noise amplified along with the signal. This noise factor is evident even though tube elements being closely spaced are designed for high-frequency operation. The spacing between the cathode and grid is as small as 0.001 inch and the cathode-to-plate spacing as small as 0.005 inch. Other design considerations that have been incorporated are smaller elements and multiple tube pin connections which reduce coupling effects of the tube elements. Engineering factors have been extended to consider such items as decreasing the size of the elements, using very short leads between the tube elements and the base pin, using multiple pin connections, making the connecting pins of special material such as chrome iron, using nickel for the connectors between the tube elements and the base pins, and plating the base pins with silver or copper to reduce the resistance factor.

16-10. The transistor r-f amplifier presents similiar problems to those encountered in tube type counterparts. For audio-frequency transitor amplifiers, it is permissible to disregard the effects of transistor internal capacitances and transit times, since these effects are negligible in the low-frequency range. Such is not the case, however, in the upper frequency ranges. Transistor internal capacitances provide feedback paths for high frequencies. Unless this feedback is controlled or eliminated, the operation of a high-frequency amplifier may be seriously impaired. Transmit times cause a falloff in gain which becomes more pronounced with increasing frequency. These effects must be taken into account when dealing with r-f and i-f amplifiers.

16-11. The transistor design has a great deal to do with high-frequency response; its alpha cutoff frequency and internal capacitances are limited factors. Desirably, it should have very low internal capacitances and its alpha cutoff frequency should be well above the required upper limit of response. Special high-frequency types such as these are available and more are being developed.

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MODIFICATIONS

Volume 2 - Supplementary Material of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

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1. *Use this Guide as a Study Aid.* It emphasizes all important study areas of this volume.

2. *Use the Guide as you complete the Volume Review Exercise and for Review after Feedback on the Results.* After each item number on your VRE is a three digit number in parenthesis. That number corresponds to the Guide Number in this Study Reference Guide which shows you where the answer to that VRE item can be found in the text. When answering the items in your VRE, refer to the areas in the text indicated by these Guide Numbers. The VRE results will be sent to you on a postcard which will list the *actual VRE items you missed.* Go to your VRE booklet and locate the Guide Number for each item missed. List these Guide Numbers. Then go back to your textbook and carefully review the areas covered by these Guide Numbers. Review the entire VRE again before you take the closed-book Course Examination.

3. *Use the Guide for Follow-up after you complete the Course Examination.* The CE results will be sent to you on a postcard, which will indicate "Satisfactory" or "Unsatisfactory" completion. The card will list *Guide Numbers* relating to the questions missed. Locate these numbers in the Guide and draw a line under the Guide Number, topic, and reference. Review these areas to insure your mastery of the course.

Guide Number	*Guide Numbers 200 through 224*
200	**Studio and Control Equipment; Studio Lighting, pages 1-3**
201	**Studio Aids, pages 3-8**
202	**Special Effects Equipment, pages 8-12**
203	**Intercom, pages 12-14**
204	**Audio and Video Equipment; Recorders: Audio Tape Recorders, pages 15-18**
205	**Recorders: Heads; Electronics; Trouble Diagnosis, pages 18-23**
206	**Recorders: Video Tape Recorders, pages 23-28**
207	**Recorders: Kinescope Recorders, pages 28-33**
208	**Projectors: 16 MM Projectors, pages 33-37**
209	**Projectors: Slide Projectors, pages 37-39**
210	**Vidicon Multiplexers, pages 39-42**
211	**Specialized Test Equipment; Monoscope Amplifiers, pages 43-45**
212	**Video Test Equipment: Grating Generator; Dot Generator; Sweep Marker Generator, pages 45-48**
213	**Video Test Equipment: Pulse Cross Display; Test Patterns, pages 48-53**
214	**Color Testing, pages 53-58**
215	**VHF Equipment; VHF Transmitters: Transmitter Principles, pages 59-62**
216	**VHF Transmitters: Transmitter Signals, pages 62-68**
217	**VHF Antennas: Transmission and Propagation; VHF Antennas, General; Factors Affecting Efficiency; Power-Handling Capabilities; Impedance Matching, pages 68-71**
218	**VHF Antennas: Baluns; VHF Antennas, Special Types; Color Television Antenna Requirements, pages 72-79**
219	**VHF TV Receivers, pages 79-87**
220	**UHF Equipment; Transmitters: Comparisons, pages 88-93**
221	**Transmitters: UHF Relay (Microwave); Transmitter Maintenance, pages 93-98**
222	**UHF Antennas: UHF Transmission and Propagation; Receiving Antennas, pages 98-100**
223	**UHF Antennas: UHF Transmitting Antennas; UHF and VHF Antennas Compared; Waveguide, pages 100-104**
224	**UHF Receivers, pages 104-107**

CHAPTER REVIEW EXERCISES

The following exercises are study aids. Write your answers in pencil in the space provided after each exercise. Immediately after completing each set of exercises, check your responses against the answers for that set. Do not submit your answers to ECI for grading.

CHAPTER 1

Objectives: To identify types, sources, and methods of controlling studio lighting; and to determine maintenance and repair procedures for such studio aids as prompters, projectors, special effects, and intercom equipment.

1. Match the descriptions in Column B to the terms in Column A by writing the alphabetical designators of Column B in the blanks of Column A.

Column A	*Column B*
______1. Base lighting.	*a.* General overall diffused illumination.
______2. Key lighting.	*b.* Additional illumination of a principal subject from a given source.
______3. Fill lighting.	*c.* Added diffused illumination to reduce shadows.
______4. Effects lighting.	*d.* Lighting which simulates a realistic scene.

(1-3-6)

2. Does the incandescent lamp have a stronger or weaker energy output at the greater wavelengths? (1-9, 10, fig. 1)

3. Which of the two common camera pickup tubes would be more suitable for use with low-intensity lighting? (1-11)

4. Is the incandescent or fluorescent lighting preferred for TV studio illumination? (1-12)

5. A spotlight with an adjustable iris and shutter would be an aid to ____________________ in a studio. (1-13, 16)

6. Which one of the following lenses—8½ inch, zoom, or 25-inch—would be the best substitute for a 90mm lens on a studio camera? (1-20, 22)

7. Name several types of equipment which are often used for TV prompting. (2-2)

8. Name the basic sections of the scroll type of prompting unit. (2-3)

9. Name the components contained in the scroll section. (2-3)

10. What are the primary maintenance requirements of the TV prompter unit? (2-5)

11. During operation the d-c synchronous motor runs very slowly in the forward direction, but reverse speed is normal. Later checks disclose that V2 plate voltage is normal and the plate voltage of V1 is low. What is a possible trouble? (2-6, fig. 3)

430.

12. The ________________ stage is more practical than the ________________ stage when projecting opaque objects. (2-8)

13. The first law governing mirror action states that the ________________ angle and ________________ angle are ________________. (2-9)

14. What disadvantage is characteristic of a semitransparent mirror? (2-10)

15. All projected images must operate along the same ________________. (2-11)

16. What is the primary functional difference between projector and camera lens assemblies? (2-12)

17. Lighting methods differ according to the application; pictures are lighted from the ________________, and slides are lighted from the ________________. (2-13)

18. List the five factors which determine the amount of illumination required for a rear screen projection. (2-14)

19. Why must the projection screen diffuse light? (2-20)

20. When selecting a projection screen, two properties that you should consider are its light ______________ and ______________ characteristics. (2-21)

21. Give the symptom for each of the following discrepancies.

a. Dirty mirror.
b. Open fuse.
c. Cloudy lamp.
d. Open lamp.
e. Broken mirror.
f. Too much angle between projector and screen.
g. Dirty lens.
h. Shorted dimmer control.
(2-22-27)

22. Why is it so important to keep the lens and mirror surfaces clean? (2-23)

23. The special effects generator provides a ______________ signal which determines the ______________ video signal produced by the ______________. (3-1)

24. Name the inputs to a special effects generator. (3-1, fig. 6)

25. What change(s) in figure 8 are necessary if a regenerative clipper incorporates n-p-n transistors connected for C-E operations? How is the output signal affected? (3-4-7, fig. 8)

26. Describe the input to a regenerative clipper that is needed to produce the special effects pattern illustrated in figure 7, A, and 7, D. (3-8-10, fig. 7)

27. Identify four pertinent signals that are formed in the special effects generator. (3-11)

28. What waveform is absent if the pattern of figure 7, B, is seen when the pattern of figure 7, C, is selected? Name some checks that can be made to locate the trouble in the special effects system. (3-11, 12, 18, figs. 7, 10, 12)

29. Sketch a block diagram showing the principal sections of a special effects amplifier. (3-14, fig. 11)

30. From figure 12 determine whether each component named below is conducting or cut off when the keying signal is at its low level.

a. Q1 ____________________.
b. D2 ____________________.
c. D3 ____________________.
d. Q5 ____________________.
e. Q3 ____________________.
(3-15-17, fig. 12)

31. Explain how the black level balance corrects for undesirable differences between the picture 1 and picture 2 side of the switching network shown in figure 12. (3-18, figs. 7, 12)

32. A headset is working, but you find that an internal spring contact is weak. You replace the contact. What type of maintenance would this be? (4-4)

33. A normal repair procedure for repair of an earpiece or a microphone is to ________________ the insert. (4-5)

34. Draw a diagram and name the parts of an intercom system necessary to provide two-way communication between offices. This would be used by maintenance personnel for adjusting CCTV systems. (4-8, fig. 13)

CHAPTER 2

Objective: To describe and analyze the principles and procedures required to operate, align, and adjust audio and video equipments to include recorders, film projectors, and multiplexers.

1. The three functions of audio tape recorders are ________________, ________________, and ________________ of audio frequencies. (5-3)

2. The ________________, ________________, and ________________ are the three main sections of an audio tape recorder. (5-4)

3. Explain why a braking facility is necessary in the tape transport mechanism of an audio tape recorder. (5-6)

4. Explain why a laminated core is preferred over a nonlaminated one in the construction of audio tape recorder heads. (5-10)

5. Why is a bias oscillator used in many audio tape recorders? (5-13, 16, 17)

6. Describe the purpose of equalization in an audio tape recorder. (5-21)

7. If the bias oscillator in figure 20 of the text failed, what would be the audio indication on a re-recorded tape? (5-25)

8. A basic difference in audio and video heads is that the ____________________ is a moving head assembly. (5-30)

9. Much of the electronic circuitry of a video tape machine is concerned with ____________________ systems. (5-34, 40, 41, 45)

10. The video tape transport must be more rigid than a tape transport for audio only, because the video tape is under ________________ and it must withstand high ________________ stops. (5-41)

11. The variable oscillator is controlled by a video frequency of ________________ to ________________ which results in an FM recording. (5-45)

12. Sometimes the cause of a weak signal on playback can be corrected by mechanically increasing the ________________ clearance of the special tape guide. (5-47)

13. A video tape could be partially erased through ________________ of the recorded tape. (5-49)

14. List the basic equipment required for kinescope recording of a television program. (5-52)

15. With reference to kinescope recordings, what are the conversion requirements for synchronization of the motion picture camera with the television system? (5-59)

16. What is the cycling pulse which controls the synchronization process in kinescope recording? (5-63, fig. 33)

17. Differentiate between the single-film system and the double-film system of television recording. (5-68)

18. Maintenance of kinescope recording equipment consists chiefly of ____________ rather than ____________ maintenance. (5-73)

19. What are the basic requirements which must be met before a 16mm film projector is considered compatible with the television system? (6-2)

20. The scanning sequence 2-3-2-3 is common for each ____________ film frames and ____________ television frames. (6-4, 5)

21. If the shutter were found to be operating when pulldown is taking place and the image is being projected during vertical blanking, what is a possible cause of the trouble? (6-6, 7)

22. The ____________ intermittent is best for use with damaged film while the ____________ intermittent extends film life. (6-11)

23. Explain why various cleaning materials must be used in different sections of the 16mm film projector. (6-19)

24. Why would a slide projector with dual optical paths be preferred to a slide projector with a single optical path? (6-23)

25. What is the most efficient method of transferring light from one optical path to another in the dual path slide projector? (6-31)

26. Explain why periodic maintenance functions are important for slide projectors. (6-33, 34)

27. Name the primary functions of a vidicon multiplexer. (7-1, 11)

28. What two major components make up the optical path of the multiplexer? (7-8, 9)

29. If you cannot move the mirror illustrated in figure 41 of the text, what is a possible cause of the problem? (7-8, 10, 11)

30. Name some of the major maintenance requirements of a multiplexer. (7-16)

CHAPTER 3

Objectives: To define the purpose of certain specialized television test equipment and to interpret the pattern presentations of each.

1. The monoscope amplifier is actually a special item of test equipment, however, its circuits are comparable to those of a ____________________ . (8-1)

2. A monoscope amplifier can be used in a TV system to provide a standardized (8-1)

3. List the quality checks which can be accomplished by using the monoscope pattern presentation. (8-5)

4. What part of the monoscope test pattern is used to check streaking? (8-8)

5. What circuits are checked and adjusted with the aid of the grating generator? (9-2)

6. You are using a grating generator to check a monitor and notice that the aspect ratio is compressed at the top and stretched at the bottom. This will require adjustment of the (9-7)

7. What adjustment of a color monitor can be made with the aid of a grating generator? (9-7; 10-15)

8. Adjusting the signal clipper bias so an output occurs when the vertical and horizontal pulses cross will result in a ____________________ pattern. (9-8)

9. What piece of test equipment, in addition to a scope, would be most useful when checking the frequency response of a linear amplifier? (9-10,11)

10. Which item of test equipment would you use to make an operational check of a sync generator? (9-12)

11. Look at the pulse cross display of figure 52 and determine how many lines of video are represented by F. (9-16, fig. 52)

12. Which would have the greater picture resolution—a 3-MHz or a 4-MHz video bandpass system? (9-17)

13. List the items which can be checked with the aid of the standard resolution chart. (9-18)

14. Which standard chart would you use in conjunction with the grating generator pattern to adjust linearity and aspect ratio? (9-25)

15. Match the item of test equipment to the associated stem.

______*a.* Linearity checker.
______*b.* Color-bar generator.
______*c.* Color signal analyzer.
______*d.* Vectorscope.

1. Provides a means of measuring the differential gain and phase distortion of transmission systems.
2. Provides a reference signal which can be used to check many aspects of color receivers and monitors.
3. It has an adjustable phase-shifting network providing a 360° (in 1° increments) shift.
4. Produces a pattern of lines and dots corresponding to colors.

(10-2, 4, 8, 12)

CHAPTER 4

Objectives: To recognize and specify the requirements of a VHF television transmitting system including signal characteristics, transmitter components, special filters, transmission lines, and antennas; to identify the maintenance requirements of VHF television transmitters; and to identify, analyze, and state the maintenance procedures of certain sections of VHF television receivers.

1. A basic transmitter is nothing more than an ____________________. (11-2)

2. What does the abbreviation MOPA stand for? (11-4)

3. List the three methods of coupling. (11-5)

4. To achieve a uniform response to a small band of frequencies, would you choose loose coupling, close coupling, or a compromise between the two? (11-6)

5. Identify the transmitter(s) necessary to initiate a complete TV broadcast. (11-10)

6. Once a visual transmitter is modulated, all the following amplifier stages must be ______________________ in operation. (11-12)

7. How many MHz wide is a broadcast TV channel that carries both the aural and visual signals? (11-13)

8. What are the stability requirements for visual and aural carrier signals? (11-13)

9. State the difference between co-channel and adjacent-channel stations. (11-15)

10. What equipment is used between the final r-f stage and antenna system to suppress the unwanted sideband of a TV signal? (11-17)

11. What is the difference in center frequency deviation used for FM radio broadcasting and TV aural signal? (11-27)

12. State the basic function of a diplexer. (11-28)

13. One advantage of negative transmission is that "noise" produces ________________ streaks or spots. (11-31)

14. If you are tuning a stage and cannot get a "dip" on a cathode meter, what would you check first? (11-33-37)

15. What one term would best describe the difference between a monochrome and a color transmitter? (11-40)

16. Why is a transmission line which is efficient for low-band VHF operation not also efficient for UHF operation? (12-7)

17. Compare and analyze VHF TV transmitting and receiving antennas with respect to the following characteristics: (a) polarization, (b) bandwidth, (c) directivity, (d) gain, and (e) insulation requirements. (12-11-26)

18. Explain how the center input impedance of a folded dipole antenna compares with that of a basic dipole antenna. (12-14, 15)

19. How may the bandwidth of a dipole antenna be increased? (12-21)

20. Why is it generally desirable to mount TV transmitting and receiving antennas as high as is economically and structurally practical? (12-24)

21. Although it is desirable that the antenna impedance equal the impedance of the TV receiver, it is more important that the characteristic impedance of the transmission line match the impedance of the ____________________. (12-27, 28)

22. A balun is a device used to convert ____________________ to ____________________ feed systems, or vice versa. (12-29-31)

23. Describe the electrical characteristics of a Yagi antenna. (12-34)

24. The fanned type conical antenna is a popular (broad/narrow) band VHF TV (transmitting/receiving) antenna. (12-37)

25. What makes it possible to predict the operational characteristics of a log-periodic antenna for many frequencies if the characterisitcs of one period of frequency are known? (12-38)

26. What are the advantages of the superturnstile antenna compared to the basic turnstile antenna? (12-41-44)

27. The antenna shown in figure 83 in the text uses the slot radiation principle. How does it get the name "traveling wave"? (12-45, 46)

28. Assuming that a radiation pattern in the normal mode (perpendicular to the antenna axis) is desired from a helical antenna, the helix dimensions should be (large/small) in comparison with a wavelength. (12-48)

29. Generally speaking, the requirements of an antenna for color TV reception are quite (different from/similar to) those for black and white TV reception. (12-51-53)

30. List the sections of a VHF TV receiver. (13-2)

31. State the function of the fine tuning control. (13-9)

32. Which would normally be the best configuration for r-f and i-f frequency modulation: a common-base (CB), a common-emitter (CE), or a common-collector (CC) amplifier? (13-12)

33. If you substitute an n-p-n type transistor for a p-n-p type transistor, what else must also be changed? (13-17)

34. What are the undesirable characteristics of a diode detector? (13-24)

35 A discriminator circuit is used in conjunction with what signal? (13-25)

36. Maintenance of a TV receiver means its care and upkeep; also included is the ______________ . (13-28)

37. Give a logical procedure for finding a faulty component in a TV receiver. (13-28-30)

38. List the basic differences in monochrome and color TV receivers. (13-31)

CHAPTER 5

Objectives: To describe the requirements of a UHF transmission system including transmitters, antennas, microwave relay and special receiver components; to identify and state the maintenance requirements of UHF transmitters and receivers.

1. UHF equipment used for TV broadcast covers what range of frequencies? (14-2)

2. List the microwave frequency bands available to be used in conjunction with TV signal relay (14-4)

3. What is the distinguishing characteristic of an amplifier which makes use of distributed properties? (14-11)

4. List the basic microwave equipment necessary to relay TV signals from a studio to a remote transmitter. (14-21)

5. The electron beam in a klystron is modulated by varying the electron (14-23)

6. What causes an electron to reverse its direction of travel in a reflex klystron? (14-27)

7. Fine tuning of a klystron can be accomplished by a slight change in ____________________.
(14-30)

8. Where would you apply the multiplexed aural and visual signal to a klystron? (14-32)

9. Why is UHF and microwave equipment sometimes more difficult to maintain than equipment operating at lower frequencies? (14-33)

10. Give a possible cause for a change in cavity resonance during normal operation. (14-33)

11. Describe the directivity and gain characteristics of a corner reflector antenna used for UHF TV reception. (15-6)

12. The basic V-type antenna is a (broad/narrow) band, (omnidirectional/bidirectional/unidirectional) antenna capable of covering both VHF and UHF bands. (15-8, 9)

13. The bow-tie antenna is a (broad/narrow) band, unidirectional antenna which provides satisfactory UHF TV reception in (weak/strong) signal areas. (15-10, 11)

14. Why are parabolic reflectors generally used in TV microwave relay systems rather than in VHF and UHF TV systems? (15-12, 13)

15. The slotted loop (slotted ring) antenna is generally used as a high-band VHF and UHF TV (transmitting/receiving) antenna. (15-18)

16. How can the gain of the slotted loop antenna be increased? (15-21)

17. How do UHF and VHF antennas compare with respect to size, bandwidth, and impedance matching requirements? (15-25, 26)

18. Explain the various ways in which the use of waveguides increases the efficiency of microwave transmission. (15-27)

19. When using the double conversion method with UHF TV, how many oscillators are necessary? (16-3)

20. How is the capacitance changed during alignment of a UHF tuner to insure proper tracking? (16-6)

21. Give a basic description of a microwave receiver. (16-7)

22. How is the noise removed from the microwave receiver? (16-8)

23. What type of tube is frequently used for a local oscillator in a microwave receiver? (16-9)

24. A common consideration when selecting tubes or transistors is their ____________________ time. (16-10)

ANSWERS FOR CHAPTER REVIEW EXERCISES

CHAPTER 1

1. 1. *a.*
   2. *b.*
   3. *c.*
   4. *d.*

   (1-3-6)
2. Stronger. (1-9, 10, fig. 1)
3. Image orthicon. (1-11)
4. Incandescent. (1-12)
5. Control the lighting. (1-13, 16)
6. Zoom. (1-20, 22)
7. Front and rear screen projectors, semitransparent mirrors, scroll, and cue cards. (2-2)
8. Scroll, d-c amplifiers, control section/power supply, and remote control. (2-3)
9. D-c synchronous motor, gear train, reels, and paper. (2-3)
10. Clean and inspect the equipment, and replace or repair all defective components. (2-5)
11. Dirty relay contacts, K1. (2-6, fig. 3)
12. Horizontal, vertical. (2-8)
13. Incidence, reflection, equal. (2-9)
14. Absorption. (2-10)
15. Optical axis. (2-11)
16. Projector lenses are not required to control light quantity, whereas camera lenses do control light quantity. (2-12)
17. Front, rear. (2-13)
18. *a.* Front light.
    b. Slide density.
    c. Type of scene.
    d. Screen size.
    e. Fall-off.
    (2-14)
19. So light will not pass directly through the screen and into the camera lens. (2-20)
20. Absorption, reflection. (2-21)
21. *a.* Low light level.
    b. No power.
    c. Low light level.
    d. No light from that stage.
    e. No image from that stage.
    f. Keystone effect.
    g. Low light level.
    h. Maximum light with no control over brightness.
    (2-22-27)

22. Dirt decreases efficiency. (2-23)

23. Keying, montage, special effects amplifier. (3-1)

24. Horizontal and vertical drive signals. (3-1, fig. 6)

25. Polarity of biases must be changed to positive if n-p-n transistors are employed in figure 8. The d-c reference level of the output signal becomes positive, but the waveforms and phase relationships are unaffected. (3-4-7, fig. 8)

26. To produce the keying signal (square wave) for the pattern in figure 7,A, the regenerative clipper is driven with a sawtooth having the horizontal scan frequency. For the pattern in figure 7,D, a triangular signal having the horizontal scan frequency combined with a sawtooth having the field scan frequency must be used as the input to the regenerative clipper. (3-8-10, fig. 7)

27. *a.* Triangular 15.75-kc signal.
    b. Sawtooth 15.75-kc signal.
    c. Triangular 60-cps signal.
    d. Sawtooth 60-cps signal.
    (3-11)

28. The pattern in figure 7,C, needs both a horizontal and vertical sawtooth signal to produce the keying signal, whereas the pattern in figure 7,B, is produced when only a vertical sawtooth is used. For these reasons, the trouble described indicates the absence of the horizontal sawtooth input to the regenerative clipper. To locate the trouble, select on the S.E. generator panel the pattern in figure 7,A. If pattern appears, the selector circuit for figure 7,C, is faulty. If pattern is blank, check the keying signal input to the special effects generator. A normal signal locates the trouble in the switcher section of the S.E. amplifier; no signal means S.E. generator trouble. Observe waveform at TP2 in figure 10. If normal, check output of K1. No signal at TP2 localizes the trouble to the H-sawtooth generator. (3-11, 12, 18, figs. 7, 10, 12)

29. Check your sketch with figure 11. (3-14, fig. 11)

30. *a.* Conducting.
    b. Cut off.
    c. Conducting.
    d. Cut off.
    e. Conducting.
    (3-15-17, fig. 12)

31. The black level balance adjust (fig. 7) changes the bias of Q1 and Q2 oppositely until both conduct equally. (3-18, figs. 7, 12)

32. Preventive maintenance; an actual breakdown has not occurred. (4-4)

33. Replace. (4-5)

34. See figure 13 and use only one headset and microphone in each place or use the telephone which would be the same circuit. (4-8, fig. 13)

CHAPTER 2

1. Recording, erasing, playing back. (5-3)
2. Transport mechanism, heads, electronics. (5-4)
3. To keep the tape from becoming tangled. (5-6)
4. Reduction of magnetic losses due to eddy currents, thus better response to high frequencies. (5-10)

5. To provide a high frequency for tape erasing and to serve as a source of bias current for the record head so that it will operate on the linear portion of its curve. (5-13, 16, 17)
6. To equalize the voltages of high and low frequencies. (5-21)
7. The old signal would not be erased. The new signal would be weak and distorted. (5-25)
8. Video. (5-30)
9. Servo. (5-34, 40, 41, 45)
10. Greater tension, speed. (5-41)
11. D-c to 4 MHz. (5-45)
12. Negative. (5-47)
13. Rough handling. (5-49)
14. *a.* A television monitor.
    b. A motion picture camera.
    c. A sound camera or recorder.
    (5-52)
15. Conversion of 30 television frames to 24 motion picture frames. (5-59)
16. An electronic pulse from the recording camera. (5-63, fig. 33)
17. *a.* Single-film system: sound and picture recorded on same camera film.
    b. Double-film system: sound and picture recorded by separate cameras.
    (5-68)
18. Preventive, corrective. (5-73)
19. Conversion, synchronization, and adaptability of the projection cycle. (6-2)
20. 4, 5. (6-4, 5)
21. A defective synchronizing waveform generator or a defective unique-phase synchronous motor. (6-6, 7)
22. Claw, sprocket. (6-11)
23. Some sections and components are delicate, while others are very sturdy. (6-19)
24. Provides more versatility. (6-23)
25. A sliding mirror. (6-31)
26. To prevent malfunctions and thus insure optimum operation. (6-33, 34)
27. Select or mix the output from several inputs and thus provide more versatility. (7-1, 11)
28. Field lens and mirrors. (7-8, 9)
29. A defective solenoid or gear train. (7-8, 10,11)
30. Clean, lubricate, and inspect. (7-16)

CHAPTER 3

1. Film camera. (8-1)
2. Test pattern. (8-1)

3. *a.* Resolution capabilities.
   b. Low-frequency phase shift.
   c. Contrast.
   d. Deflection linearity.
   e. Transmitter quality and performance tests.
   f. Receiver performance.
   (8-5)

4. Horizontal lines beneath the center circle. (8-8)

5. Deflection circuits. (9-2)

6. Vertical linearity. (9-7)

7. Convergence. (9-7; 10-15)

8. Dot. (9-8)

9. Sweep marker generator. (9-10, 11)

10. Pulse cross display. (9-12)

11. Three (since a video scan is 1H and F represents 3H). (9-16, fig. 52)

12. 4 mc. (9-17)

13. *a.* Resolution.
    b. Geometric distortion.
    c. Aspect ratio.
    d. Shading uniformity.
    e. Streaking.
    f. Gray-scale reproduction.
    g. Interlace.
    h. R-f interference.
    i. Frequency response.
    j. Brightness.
    (9-18)

14. Standard linearity chart (by focusing the camera on this chart and superimposing the grating pattern on the presentation). (9-25)

15. *a.* 1.
    b. 2.
    c. 3.
    d. 4.
    (10-2, 4, 8, 12)

CHAPTER 4

1. Oscillator connected to an antenna. (11-2)

2. Master oscillator power amplifier. (11-4)

3. *a.* Capacitive.
   b. Inductive.
   c. Link.
   (11-5)

4. Compromise of the two methods. (11-6)

5. It is necessary to have an AM visual transmitter and an FM aural transmitter. (11-10)

6. Linear. (11-12)

7. 6 MHz. (11-13)

8. Visual is ±1000 Hz and the aural is ±1000 Hz. (11-13)

9. Co-channel stations are two stations on the same frequency, while adjacent channel stations are two stations adjacent in frequency. (11-15)

10. Vestigial sideband filter. (11-17)

11. 50 KHz. (11-27)

12. A diplexer enables the transmission of multiple signals by one antenna. (11-28)

13. Black. (11-31)

14. Check to see if you have drive from the preceding stage. Then, if necessary, check the stage which you are tuning. (11-33-37)

15. Tolerance limits. (11-40)

16. With an increase in frequency, transmission line losses increase. (12-7)

17.

Characteristic	*Transmitting Antenna*	*Receiving Antenna*
a. Polarization.	Horizontal.	Horizontal.
b. Bandwidth.	6 mc.	Minimum of 6 mc (often much wider).
c. Directivity.	Omnidirectional.	Unidirectional.
d. Gain.	Good.	Excellent.
e. Insulation requirements.	Critical.	Not a matter of concern.

(12-11-26)

18. The center input impedance of the folded dipole is greater than that of a basic dipole, each additional conductor of a folded dipole further increases the center input impedance of the antenna. (12-14, 15)

19. By using antenna wire with increased diameter, by stacking dipoles one above the other, or by using a folded dipole. (12-21)

20. *a.* By mounting transmitting and receiving antennas at increased heights, the line-of-sight distance between them can be extended.
    b. Increasing the height of a receiving antenna generally places it in an area of stronger field strength. (12-24)

21. Receiver. (12-27, 28)

22. Balanced, unbalanced. (12-29-31)

23. The electrical characteristics of a Yagi antenna are high gain, unidirectional, good front-to-back ratio, and relatively narrow bandwidth; it is also used as a TV receiving antenna. (12-34)

24. Broad; receiving. (12-37)

25. Because its input impedance, radiation pattern, and active elements repeat periodically as a function of the logarithm of frequency. (12-38)

26. The stacked radiating elements of the superturnstile antenna have higher gain, increased vertical directivity, and wider bandwidth than has the basic turnstile antenna. (12-41-44)

27. From the way the slots in the antenna are fed. (12-45, 46)

28. Small. (12-48)

29. Similar to. (12-51-53)

30. *a.* R-f.
    b. I-f.
    c. Video.
    d. Sync separator.
    e. Vertical sweep.
    f. Horizontal sweep.
    g. High voltage.
    h. Low voltage.
    i. Automatic gain control (agc).
    j. Audio.
    (13-2)

31. The fine tuning control varies the local oscillator frequency, thus centering the incoming signal for proper bandpass. (13-9)

32. CB is generally preferred due to stability, controlled gain, and interchangeability. (13-12)

33. The d-c polarities must also be reversed. (13-17)

34. No power gain and selectivity are affected by loading. (13-24)

35. This is the detector for the FM signal which is the audio portion of TV broadcasting. (13-25)

36. Troubleshooting and repair of equipment. (13-28)

37. *a.* Determine if visual, aural, or both are affected.
    b. Determine the section or circuit group.
    c. Isolate to a specific stage or circuit.
    d. Locate the faulty component.
    (13-28-30)

38. *a.* Color synchronizing section.
    b. Demodulation (chrominance) section.
    c. Matrix section.
    (13-31)

CHAPTER 5

1. 470-MHz to 890-MHz range. (14-2)

2. *a.* 1990 MHz to 2110 MHz (2000-MHz band).
   b. 6925 MHz to 7050 MHz (7000-MHz band).
   c. 13,025 MHz to 13,200 MHz (13,000-MHz band).
   d. 890.5 MHz to 910.5 MHz (900-MHz band for audio only).
   (14-4)

3. The amplifier is so designed that the materials used in its construction make up circuit components. (14-11)

4. *a.* A microwave transmitter.
   b. A transmitting antenna system.
   c. A receiving antenna system.
   d. A microwave receiver.
   (14-21)

5. Velocities. (14-23)

6. The electron which leaves the cathode approaches the repeller plate which is more negative than the electron; the like charges repel and the electron travel is reversed. (14-27)

7. Repeller voltage. (14-30)

8. Apply the signal to the klystron repeller and thus modulate the output. (14-32)

9. UHF and microwave equipment is more difficult to maintain because the circuits are more critical and may be influenced by such things as dust, lint, temperature changes, and voltage variations. (14-33)

10. The tuning cavity can have its capacitance and thus its resonance changed by any particle carried into it by the cooling system. (14-33)

11. The UHF corner reflector antenna is unidirectional, with maximum signal radiated in line with the bisector of the corner angle. It has excellent gain over most of the UHF spectrum. (15-6)

12. Broad; bidirectional. (15-8, 9)

13. Broad; strong. (15-10, 11)

14. Microwave transmission is usually between two points; therefore, it is directive. The properties of microwave energy approach those of light waves; therefore, microwaves can be easily concentrated into a tight beam. Also, antenna structure is bulky for the lower frequencies. (15-12,13)

15. Transmitting. (15-18)

16. By stacking identical bays one above the other. (15-21)

17. UHF antennas are smaller. UHF antennas have broader bandwidth. (They are shorter in length; therefore, they have a smaller length-to-diameter ratio.) Impedance matching should be more carefully considered in UHF antenna systems because transmission line losses are greater at the higher frequencies. (15-25, 26)

18. Microwave transmission efficiency is increased when waveguides are used because radiation losses are less, copper losses are less, dielectric losses are less, and power-handling capability is greater. (15-27)

19. Two. (16-3)

20. By bending the tabs located in the tuner. (16-6)

21. A microwave receiver is basically an FM superheterodyne receiver with several stages of i-f amplification. (16-7)

22. The i-f signal is passed through clipper stage(s) to remove noise. (16-8)

23. Klystron. (16-9)

24. Transit. (16-10)

STOP– 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER. 2. USE NUMBER 1 PENCIL.

30455 02 21

VOLUME REVIEW EXERCISE

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use only medium sharp #1 black lead pencil for marking answer sheet.
4. Use a clean eraser for any answer sheet changes, keeping erasures to a minimum.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than with a #1 black lead pencil.

Note. The 3-digit number in parenthesis immediately following each item number in this Volume Review Exercise represents a Guide Number in the Study Reference Guide which in turn indicates the area of the text where the answer to that item can be found. For proper use of these Guide Numbers in assisting you with your Volume Review Exercise, read carefully the instructions in the heading of the Study Reference Guide.

Multiple Choice

Note: The first three items in this exercise are based on instructions that were included with your course materials. The correctness or incorrectness of your answers to these items will be reflected in your total score. There are no Study Reference Guide subject-area numbers for these first three items.

1. The form number of this VRE (or CE) must match

   a. my course number.
   b. the number of the Shipping List.
   c. the form number on the answer sheet.
   d. my course volume number.

2. So that the electronic scanner can properly score my answer sheet, I must mark my answers with a

   a. pen with blue ink.
   b. ball point or liquid-lead pen.
   c. number 1 black lead pencil.
   d. pen with black ink.

3. If I tape, staple or mutilate my answer sheet; or if I do not cleanly erase when I make changes on the sheet; or if I write over the numbers and symbols along the top margin of the sheet,

   a. I will receive a new answer sheet.
   b. my answer sheet will be unscored or scored incorrectly.
   c. I will be required to retake the VRE (or CE).
   d. my answer sheet will be hand-graded.

Chapter 1

4. (202) What is the purpose of the special effects generator?

   a. To produce a montage display.
   b. To produce a keying signal.
   c. To make it possible to receive two picture signals simultaneously.
   d. To combine the picture signals and montage display.

5. (200) What are the four major types of lighting used in television?

   a. Base, key, fluorescent, and incandescent lighting.
   b. Base, fill, fluorescent, and effects lighting.
   c. Base, fill, effects, and incandescent lighting.
   d. Base, fill, key, and effects lighting.

6. (202) How do the waveshapes and frequencies of the signals at TP3 and TP4 of the special effects generator compare with those at TP1 and TP2?

   a. The waveshapes and frequencies are the same as those at TP1 and TP2.
   b. The waveshapes are the same as those at TP1 and TP2, but the frequency of the signals is different.
   c. The waveshapes are different, but the frequencies are the same as those at TP1 and TP2.
   d. Both the waveshapes and frequencies are different from those at TP1 and TP2.

7. (201) What sections make up the scroll TV prompter?

   a. Scroll, control, power supply, and gear train.
   b. Scroll, power supply, amplifier, and gear train.
   c. Scroll, control, amplifier, and remote control.
   d. Scroll, amplifier, power supply, and control.

8. (202) What components conduct on the high-level alternation of the special effects keying signal in the special effects amplifier?

a. Q4, Q5, D1, and D2.
b. Q4, Q5, D2, and D3.
c. Q4, Q1, D3, and D4.
d. Q4, Q5, Q3, and D3.

9. (200) How is the TV light source effectively controlled?

a. By placement of the lights, size of the lights, and individual dimmers.
b. By individual dimmers, individual switches, placement, and patching of the light facilities.
c. By individual and group dimmers, individual and master switches, and size of the lights.
d. By individual and group dimmers, individual and master switches, and patching facilities.

10. (201) What operating controls could make the rear screen projector more versatile and flexible in its operation?

a. Dimmers, crawl mechanisms, light switches, iris controls, and semitransparent mirrors.
b. Dimmers, wipers, light switches, and semitransparent mirrors.
c. Dimmers, crawl mechanisms, light switches, iris controls, and wipers.
d. Dimmers, wipers, light switches, and semitransparent and front surface mirrors.

11. (201) Why are the troubleshooting and repair functions encountered in the rear screen projector relatively simple in nature?

a. Because few components become defective.
b. Because all of the components are stationary.
c. Because few of the components are movable.
d. Because of its design simplicity.

12. (202) What determines the regenerative clipper's rapid switching action?

a. The input signal.
b. The threshold potential.
c. The collector voltage.
d. The regenerative feedback.

Chapter 2

13. (207) The basic equipment required for kinescope recording of a television program must include

a. TV monitor, video camera, sound camera recorder.
b. TV monitor, video amplifier, video camera.
c. TV monitor, video amplifier, audio amplifier.
d. TV monitor, video camera, audio amplifier.

14. (207) When the shutter of the kinescope recording camera is controlled electronically, what is the duration of the blanking pulse output from the shutter gate generator?

a. $^1/_{24}$ second.
b. $^1/_{30}$ second.
c. $^1/_{60}$ second.
d. $^1/_{120}$ second.

15. (210) What unit provides for mixing several video inputs to produce one output for the camera?

a. Dual-optical slide projector.
b. Vidicon multiplexer.
c. Video recorder-reproducer.
d. Video distribution system stabilizing amplifier.

16. (204) The erase head of an audio tape recorder fails to erase the previous recording when a new recording is made. Which of the following is a possible cause?

    a. Tape and heads are out of alignment.
    b. Capstan and capstan pressure roller are out of alignment.
    c. Transport mechanism is inoperative.
    d. Record head is inoperative.

17. (206) Which of the following represents a major maintenance problem of a traverse video tape recorder?

    a. Lubrication.
    b. Tube replacement.
    c. Head tip wear.
    d. Equalization.

18. (206) The relationship between wavelength, frequency, and tape velocity is expressed by the formula $\lambda = \frac{V}{F}$. What occurs to the wavelength if the frequency increases as the velocity remains constant?

    a. It decreases.
    b. It remains the same.
    c. It increases in length.
    d. It disappears.

19. (210) Which of the following is a maintenance requirement of a multiplexer?

    a. Lubrication of focal throw.
    b. Adjustment of mirror transparency.
    c. Inspection of optical plane.
    d. Cleaning of mirrors.

20. (207) When the shutter of the kinescope recording camera is controlled electronically, what is the frequency of the cycling pulse?

    a. 30 pulses per second.
    b. 24 pulses per second.
    c. $^1/_{60}$ second.
    d. $^1/_{120}$ second.

21. (205) Which of the following features is employed in the construction of tape heads to reduce high-frequency losses?

    a. Laminated core.
    b. Circular shape.
    c. Magnetic filled gap.
    d. Hard steel.

22. (209) The more efficient way to transfer light from one optical path to another in a dual-optical slide projector is to use

    a. two projection lamps.
    b. a sliding mirror.
    c. a rotating slide magazine.
    d. an adjustable prism.

23. (206) What circuitry is used to maintain constant tape and rotating head speed and to reduce timing errors?

    a. Closed loop servosystems.
    b. Quadrature overlap.
    c. Electronic delay.
    d. Initial presets.

24. (207) In a single-film system, the sound of a reproduced composite television signal precedes the picture. What is a possible cause?

    a. The top loop of the camera film is too long.
    b. The top loop of the camera film is too short.
    c. The bottom loop of the camera film is too short.
    d. The bottom loop of the camera film is too long.

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25. (204) In audio tape recorders, erasing, recording, and playing back are functions of which of the following?

a. Transport mechanisms.
b. Electronic circuits.
c. Tape heads.
d. Tape handlers.

26. (208) In addition to the specially designed intermittence of the projector, what is required to convert the film frame rate to the TV frame rate?

a. A low persistent type pickup tube.
b. A pickup tube with storage properties.
c. Pickup camera synchronization.
d. Light flashes from the pickup tube.

27. (205) The high-frequency bias current insures that the signal to be recorded will fall on the linear portion of the hysteresis curve. What is another use of this bias current?

a. Audio amplifier fixed bias.
b. Head current erasure.
c. Frequency equalization.
d. Playback bias.

28. (205) In tape recorders it is standard practice to overcome the loss of high frequencies in the record amplifier, and to overcome the loss of low frequencies in the playback amplifier. Which of the following terms best describes this practice?

a. Preemphasis.
b. Deemphasis.
c. Equalization.
d. Attenuation.

29. (208) What special feature of the film projector permits moving the film in alternate steps of $^1/_{30}$ and $^1/_{20}$ seconds?

a. An ordinary synchronous motor.
b. A unique phase synchronous motor.
c. Pulses from synchronizing waveform generator.
d. Intermittent with a 3-sided Geneva movement.

30. (205) Which of the following statements best describes the purpose of equalization circuits in an audio tape recorder?

a. To provide the same output level for low and high frequencies.
b. To permit full-track or half-track recording.
c. To provide automatic gain control.
d. To maintain constant tape speed.

31. (204) Which of the following components of a tape transport mechanism reduces the effect of tape speed variations?

a. The pinch roller.
b. The tension idler.
c. The rolling tape guide.
d. The capstan.

32. (208) If there is no image from the film projector, the trouble might be caused by

a. a burned out projector lamp.
b. loss of the lower film loop.
c. loss of the upper film loop.
d. a broken intermittent claw.

33. (208) What is a desired characteristic of the moving film projector lens?

a. Short focal length.
b. High magnification.
c. Long throw.
d. Automatic zoom.

34. (213) The output of the synchronizing generator may be observed as a pulse cross display on a modified television monitor. Which of the following *best* describes the measurements that can be made with this output display?

a. Linear amplifier frequency response and bandwidth.
b. Horizontal and vertical deflection frequency rates.
c. Dynamic and static convergence.
d. Equalizing, sync, and blanking pulse widths.

35. (211) What is the purpose of the calibrated markings associated with the vertical and horizontal wedges in test pattern presentations?

a. To measure gray-scale reproduction.
b. To calculate aspect ratio.
c. To evaluate low-frequency response.
d. To determine the resolution capability.

36. (213) A modified television monitor is being used to observe a pulse cross display. What check could be in progress?

a. A resolution check.
b. The deflection linearity check.
c. A vertical blanking check.
d. The geometric distortion check.

37. (214) Which test equipment could be used to adjust the convergence of a color TV monitor?

a. Grating or dot generators.
b. Color-bar or rainbow generator.
c. Color analyzer or linearity checker.
d. Vectorscope and color-burst generator.

38. (211) Which of the following units can be used to replace a camera for test pattern transmission?

a. A grating generator.
b. A monoscope amplifier.
c. A linearity checker.
d. A resolution chart.

39. (212) Which of the following statements *best* describes one of the purposes of the video equipment known as a grating generator?

a. To generate a pulse cross display.
b. To provide equalizing pulses.
c. To check the linearity of deflection circuits.
d. To check the blanking interval.

40. (213) A monitor displays a grating pattern superimposed on a standard linearity chart presentation. Which of the following statements is correct if the grating lines intersect within the circles?

a. Geometric distortion is less than 2 percent.
b. Resolution is 500 or more.
c. Correct gray scale is present.
d. Correct interlace condition is present.

41. (211) What part of the monoscope test pattern is used to check low-frequency response?

a. The wedge lines.
b. The upper right corner wedge.
c. The station identification letters.
d. The horizontal lines beneath the center circle.

42. (214) Which combination of test equipment can be used to adjust the phase of the I and Q signals in a colorplexer?

a. Color linearity checker and color analyzer.
b. Color-bar generator and color analyzer.
c. Rainbow generator and color linearity checker.
d. Color-bar generator and chromatron.

Chapter 4

43. (219) In most TV receivers, the output of the tuner section is

a. an i-f signal.
b. an r-f signal.
c. an oscillator frequency signal.
d. a raw video signal.

44. (216) Which of the following TV stations are adjacent-channel, but may be assigned to the same city?

a. 7 and 8.
b. 5 and 6.
c. 4 and 5.
d. 3 and 4.

45. (219) What is a logical procedure for TV receiver troubleshooting?

a. Isolate the stage and locate the circuit group.
b. Locate the circuit group and then locate the component.
c. Locate the circuit group, isolate the stage, and locate the faulty component.
d. Locate the faulty component, isolate the stage, and locate the circuit group.

46. (217) The length of a dipole antenna designed for channel 10 operation (192-198 mc) should be approximately how long?

a. 4.7 feet.
b. 2.4 feet.
c. 14 inches.
d. 42 inches.

47. (219) Which transistor amplifier configuration is preferred for stability and interchangeability of components?

a. CA.
b. CB.
c. CC.
d. CE.

48. (217) Which of the following is a major purpose of a reflector placed behind an antenna?

a. To increase signal gain.
b. To increase vertical directivity.
c. To increase input impedance.
d. To increase bandwidth.

49. (216) Suppose there is no output from a transmitter whose stages are V1 (oscillator), V2 (doubler), V3 (tripler), and V4 (power amplifier). In what order would you "read" the symptoms?

a. V4, V3, V2, and V1.
b. V4, V3, and V1, V2.
c. V4, V1, V3, and V2.
d. V1, V2, V3, and V4.

50. (216) How much visual carrier frequency deviation is permissible in a television system?

a. +1000 Hz.
b. −1000 Hz.
c. ±1000 Hz.
d. ±100 Hz.

51. (219) What is the function of an AM detector circuit in a TV receiver?

a. To select, rectify, and filter the aural signal.
b. To select, rectify, and filter the video signal.
c. To select, rectify, and filter *only* the video sync pulses.
d. To select, rectify, and filter out unwanted AM stations.

52. (218) Which of the following best describes the log-periodic antenna (LPA) used in VHF TV systems?

a. A high-gain, wide-band, unidirectional receiving antenna.
b. A high-gain, wide-band, omnidirectional transmitting antenna.
c. A high-gain, narrow-band, unidirectional receiving antenna.
d. A high-gain, narrow-band, omnidirectional transmitting antenna.

53. (219) Normally, what amplifier sections of a TV receiver have agc voltage applied?

a. All i-f sections and r-f sections.
b. All i-f sections *except* the last (normally) and r-f sections.
c. All i-f sections and r-f sections *except* the second (normally).
d. The i-f sections only.

54. (217) Which characteristics greatly determine the physical size of a VHF TV antenna?

a. The operating frequency and desired radiation pattern.
b. The polarization and desired radiation pattern.
c. The operating frequency and power-handling capability.
d. The polarization and power-handling capability.

55. (218) Which of the following serves most efficiently as an omnidirectional VHF TV transmitting antenna?

a. The fanned conical antenna with reflector.
b. The three-bay log-periodic antenna.
c. The Yagi antenna.
d. The helical antenna.

56. (216) When using a meter in the cathode circuit to tune an amplifier plate circuit in a TV transmitter, the meter should show

a. maximum plate current.
b. minimum grid drive of following stage.
c. maximum grid drive of stage being tuned.
d. minimum plate current.

57. (215) Which of the following are basic types of coupling in VHF transmitters?

a. Capacitive, link, and inductive.
b. Link, capacitive, and chain.
c. Inductive, link, and chain.
d. Capacitive, chain, and inductive.

58. (218) What is the chief function of a balun?

a. To match impedances.
b. To balance asymmetrical circuits.
c. To balance antenna impedance.
d. To increase antenna gain.

59. (219) What is the purpose of the fine tuning control in the r-f section of the VHF TV receiver?

a. To trim the r-f amplifier.
b. To vary the i-f amplifier.
c. To change the frequency of the local oscillator.
d. To select the proper tuned circuit.

60. (219) What stages are replaced by use of a converter section?

a. R-f amplifier and mixer stages.
b. Oscillator and mixer stages.
c. Oscillator and r-f amplifier stages.
d. Mixer and i-f amplifier stages.

61. (216) When troubleshooting a TV transmitter, if V3 grid meter indicates grid drive and the cathode meter indicates *no* tube current, you should check the components of

a. the previous stage (V2).
b. the following stage (V4).
c. both the previous stage (V2) and the following stage (V4).
d. the stage in question (V3).

62. (219) What signals are amplified by the r-f section of a TV receiver?

a. AM video and FM audio signals.
b. Composite video and AM audio signals.
c. AM audio and sync signals.
d. FM video and sync signals.

63. (219) What is the necessary bandwidth of the r-f section of a TV receiver?

a. .25 MHz.
b. 1.25 MHz.
c. 4.50 MHz.
d. 6.0 MHz.

64. (217) The transmitting antenna serving a VHF TV broadcast station is usually

a. bidirectional.
b. vertically polarized.
c. omnidirectional.
d. narrow in bandwidth.

65. (218) Which of the following will increase the gain, directivity, and bandwidth of a turnstile antenna used for VHF TV transmission?

a. Increasing the height of the antenna.
b. Increasing the size of each radiating element.
c. Vertical stacking of individual radiating elements.
d. Balun coupling of antenna and transmitter.

66. (217) A TV antenna which has a low Q will possess

a. a high gain.
b. a broad bandwidth.
c. a narrow bandwidth.
d. an excellent directivity.

67. (217) The insulation requirements of an antenna serving a VHF TV transmitting station would most likely be reduced by increasing the

a. height of the antenna.
b. bandwidth of the antenna.
c. video transmitter output.
d. video transmitter ERP requirement.

Chapter 5

68. (220) What is the normal transmitting range of VHF and UHF equipment?

a. Both systems have an infinite range.
b. A range of 54 MHz to 216 MHz.
c. A range of 470 MHz to 890 MHz.
d. Both systems are limited to line-of-sight transmission.

69. (223) Which of the following best describes the UHF slotted loop (slotted ring) antenna?

a. High-gain, balanced conductors.
b. Low-gain, unbalanced conductors.
c. Low-gain, high-power-handling capability.
d. High-gain, low-power-handling capability.

70. (222) Which of the following is a proper comparison of UHF and VHF propagation characteristics?

a. VHF propagation characteristics are less favorable.
b. UHF shadow effect is less severe.
c. UHF line-of-sight distance is shorter.
d. VHF line-of-sight distance is shorter.

71. (224) What is double conversion in a UHF receiver?

a. The reception of two TV signals simultaneously.
b. Two stages of heterodyning to develop two i-f signals.
c. A tuner with two r-f paths.
d. Detecting two r-f signals with one i-f stage.

72. (224) How does a microwave receiver differ from a TV receiver?

a. It uses fewer i-f stages.
b. It uses r-f amplifier stages.
c. It has a narrower bandpass.
d. It uses a klystron local oscillator.

73. (220) Under what conditions, if ever, will the UHF transmitter have the same basic circuits as the VHF transmitter?

a. The transmitters never have the same basic circuits.
b. The transmitters have the same basic circuits at the higher frequency levels.
c. The transmitters have the same basic circuits at the lower frequency levels.
d. The circuits are the same when transmitting video signals only.

74. (223) Why are waveguides more efficient than transmission lines for microwave transmission?

a. Waveguides have less signal attenuation.
b. Waveguides have no standing waves.
c. Waveguides present no impedance matching problems.
d. Waveguides permit the antenna to be more directive.

75. (221) What is velocity modulation?

a. A variation in the number of electrons.
b. The speed of an electron beam.
c. Electrons striking a resonant cavity.
d. A variation in the speed of electrons.

76. (223) UHF antennas are less subject to interference from the surrounding area than VHF antennas because the

a. VHF antennas are longer.
b. VHF wavelengths are longer.
c. UHF antennas are shorter.
d. UHF wavelengths are shorter.

77. (221) Why does a UHF microwave transmitter require more careful maintenance than a standard AM transmitter?

a. It has wide-band circuits that are sensitive to changes.
b. There is more heat generated that causes circuit changes.
c. The circuits use larger components that require constant tuning.
d. Standing waves are constantly changing and must be tuned out.

78. (222) Which of the following is a characteristic of the UHF TV bow-tie antenna?

a. Narrow bandwidth.
b. Broad bandwidth.
c. Omnidirectional.
d. Vertical polarization.

79. (220) From the information in the text, what does a UHF power amplifier have that a VHF power amplifier does *not* have?

a. Four coaxial cavities.
b. Two more coaxial tetrodes.
c. Larger capacitors.
d. Larger inductors.

80. (222) The input impedance of a corner reflector antenna can be increased by

a. using a balun between the antenna and transmission line.
b. mounting the antenna in the vertical plane.
c. using a folded dipole for the driven element.
d. increasing the height of the antenna.

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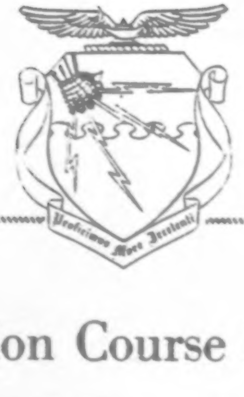
CDC 30455

TELEVISION EQUIPMENT REPAIRMAN

(AFSC 30455)

Volume 3

Systems Maintenance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Preface

THIS FINAL VOLUME of CDC 30455 contains information necessary for the proper maintenance of television systems. Chapter 1 deals with operational responsibilities. more specifically. publications. types of inspections. and quality checks. as well as the duties and responsibilities of inspection teams. In Chapter 2. we develop troubleshooting and repair procedures as they apply to both test equipment and television equipment. In addition. proposals for correcting recurring equipment malfunctions are discussed. Finally. the responsibilities for repair. calibration. and certification of precision-measuring equipment are stated. Television system troubles are described and the symptoms diagnosed in Chapter 3. Our final chapter is devoted to C-E planning. programming. and the related PC and PCSP documents. A discussion of siting. installation. and the various types of acceptance tests necessary for new television systems is also included. Finally. the need for modification is discussed.

If you have questions on the accuracy or currency of the subject matter of this text. or recommendations for its improvement. send them to Tech Tng Cen (TSOC). Keesler AFB. MS 39534.

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MODIFICATIONS

Chapter 1 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

CHAPTER 2

Troubleshooting and Repair

IN THIS CHAPTER we will discuss the types of test equipment used at a television installation, as well as their purpose, use, and common failures. When test equipment failures are encountered, alternate testing methods must be available; therefore, we will discuss some of these alternate testing methods. General television system troubleshooting methods and procedures that are needed to maintain a system in proper operating condition will be discussed: in addition, television equipment alignment and calibration procedures are developed. We will also describe the advantages of using bench mockups over other testing methods. Finally, the responsibilities for the repair, calibration, and certification of precision measuring equipment are explained.

4. Television Test Equipment, Types, Use, and Malfunctions

4-1. This section states the types of test equipment necessary to maintain various television system configurations properly. In addition, we will identify some alternate system testing methods and describe how each is accomplished. Likewise, alternate transistor tests and precautions are discussed. Finally, we will identify some test equipment malfunctions and describe the related symptoms.

4-2. **Television Test Equipment.** The normal procedure of troubleshooting closed-circuit and r-f television systems is through tests made to determine the character of the video and audio signals; to evaluate the performance of the television equipment; to maintain and repair the equpment; or to determine peculiarities of individual equipments. The majority of these functions and tests can be made with standard shop test equipment, such as tube checkers, wattmeters, voltmeters, ohmmeters, milliammeters, and dummy loads. However, the oscilloscope and video sweep generator are particularly applicable to television testing, while the multiburst generator, grating generator, monoscope amplifier (camera), and waveform monitor are generally considered as specialized test equipment designed for television system quality testing.

4-3. *Ohmmeters, voltmeters, and milliammeters.* These general types of metered test equipment are normally used in the final stages of troubleshooting. This may entail finding the failed component of an inoperative circuit. However, the voltmeter and milliammeter may also be used while you make some relatively simple system maintenance checks. These checks usually consist of monitoring the output of the regulated power supplies and similar operations. In addition, they are used to make some types of voltage and current measurements during PMI's, where metered measurements are required. It must be understood that oscilloscope voltage measurements are much more accurate; thus, they are more desirable for critical readings.

4-4. *Tube checker.* A tube checker is normally used during PMI's and when a tube's condition is doubtful. Some television equipment peculiarities extend the usefulness of the tube checker beyond locating defective tubes. Television equipment using balanced modulator circuits is an example, inasmuch as the tubes must be closely matched under such conditions. Therefore, the tube checker can be used to "match" tubes in pairs from the bench stock, thereby saving a considerable amount of money. Tubes that are purchased in matched sets are much more expensive.

4-5. *Dummy loads and wattmeters.* When performing PMI's and troubleshooting functions on transmission equipment, dummy loads and wattmeters are often needed. Their use will prevent r-f interference with other operations which may be going on at that time. The dummy loads and wattmeters selected for television maintenance must have adequate power handling capabilities to handle the high-power output of the video transmitter satisfactorily.

4-6. *Cathode-ray oscilloscope.* A cathode-ray oscilloscope suitable for television application is specifically designed for maintenance, alignment, and adjustment of that equipment. It must present accurately all of the video waveforms that are employed in a television broadcast installation.

4-7. By using an oscilloscope designed for television, you can observe any portion of the television picture waveform, from complete televison picture frames to small segments of individual scanning lines, as well as waveshape, width, and amplitude. The oscilloscope thus provides an accurate means of measuring both amplitude and time of television signals, in addition to presenting a detailed representation of the picture signal. Consequently, the oscilloscope is adaptable for both troubleshooting and system maintenance.

4-8. *Video sweep generator.* The video sweep generator is used to inject a signal through a circuit under test. Thus, the oscilloscope measurement of signal amplitude is possible. The overall response of the tested circut with respect to its frequency characteristic can be obtained. Use a video sweep generator when adjustment of camera preamplifiers and bandpass of other video circuits is necessary.

4-9. *Multiburst generator.* The multiburst generator is primarily used for complete television broadcast facility operational checks. However, while it is limited when used to test individual components or circuits, it can be used like the sweep generator in some respects, such as providing the signal to a circuit under test and for measurement of the circuit output amplitude versus frequency response. The advantage of using this instrument is that no tested circuitry need be disabled or disconnected. The generator will apply test signals, simulating actual television signal frequencies, and feed them directly into the television facility for an operational response. The multiburst generator provides an output consisting of bursts, or groupings, of various frequencies superimposed on the pedestal, with standard blanking and synchronizing signals added. As shown in figure 1, all bursts must be of equal amplitude for application to the input of the television broadcast facility. Changes of waveform amplitude, as observed on an oscilloscope connected at either the facility output or other convenient checkpoint, will indicate circuit or network frequency response deviations at particular frequencies. However, this check does not isolate a malfunctioning circuit; it only indicates a malfunction of the system.

4-10. *Grating generator.* The grating generator provides a pattern which is a convenient method of testing and adjusting both the horizontal and vertical linearity of the television deflection circuits. This test provides checks for deviations in picture characteristics, such as picture compression or expansion resulting from nonuniform scanning velocity that may be caused by the deflection circuits.

4-11. *Monoscope amplifier (camera).* The monoscope amplifier (camera) unit, as you already know, is a suitable means of checking resolution, low-frequency phase shift, contrast, and deflection linearity of the television broadcast equipment. It also provides a modulating signal for transmitter tests and receiver performance.

4-12. *Waveform monitor.* The waveform monitor is a specialized type of oscilloscope which provides detailed and varied video information. It is capable of presenting many video combina-

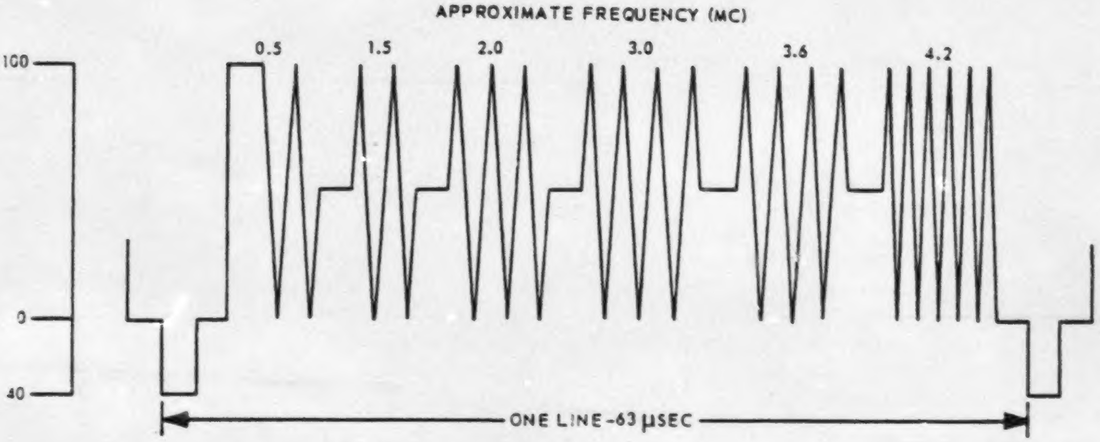

Figure 1. Multiburst generator output test signal.

tions from a complete television frame to a single segment of a desired line or even a single pulse shape or edge. Consequently, the waveform monitor is much more adaptable to television testing than is the average oscilloscope. Its uses are much the same as other types of oscilloscopes; however, it is more suitable for system tests than for individual circuit or circuit component troubbleshooting.

4-13. **Color Television Testing.** In addition to the previously mentioned items of test equipment, the proper maintenance of a color television broadcast system necessitates the use of more specialized and refined test equipment. Such equipment as the dot generator, color bar generator, vectorscope, color signal analyzer, and linearity checker are used to provide the proper test signals.

4-14. *Dot generator.* The dot generator provides a pattern which is primariy used for convergence and registration checks of color television monitors and receivers. However, it is also used for system maintenance checks.

4-15. *Color bar generator.* A color bar generator provides rectangular pulses for application to the red, blue, and green input circuits of a colorplexer. This will produce a color bar test pattern at the colorplexer output. The pattern is used to check the color quality of an entire color television system.

4-16. *Vectorscope.* The vectorscope permits inspection of the amplitudes and phase relations of the color subcarrier signals. A vectorscope is particularly valuable for checking the phase amplitudes of the color outputs from the colorplexer. Again, the vectorscope is primarily used to check the color quality of the system.

4-17. *Color signal analyzer.* This test instrument is used to study the components of a composite color video and subcarrier signal. When the typical color signal analyzer is used in conjunction with a color bar generator and oscilloscope, you can measure the phase relations between the subcarrier burst reference and the different components of the composite color signal. In addition, the color signal analyzer used in conjunction with a linearity checker will provide a method of obtaining differential phase measurements.

4-18. *Linearity checker.* Linearity checkers are primarily signal generators which provide a simulated color video signal. The typical linearity checker is used to measure both the differential gain and differential phase distortion of video amplifiers and transmission facilities. The linearity checker is more valuable since the gain and phase linearity of color television signals must be maintained at a high level.

4-19. **Test Equipment Malfunctions and Detection.** Test equipment malfunctions are usually discovered during operation since test equipment is not normally maintained in a continuous operating condition. Because of the differences in test equipment, indications of equipment failures will manifest themselves in various ways. The most reliable means of isolating test equipment problems, as in other types of electronic equipment, is through substitution of a like item. Thus if the alternate unit operates properly, the original unit is faulty. Many of the problems encountered in television test equipment will be visually apparent since the primary function of this test equipment is video alignment and testing.

4-20. *Oscilloscopes and waveform monitors.* The most obvious problems in oscilloscopes and waveform monitors are lack of vertical or horizontal deflection, unstable display, no video display, and loss of operating voltage.

- Loss of vertical deflection is indicated when the visual display has no height; consequently, the problem is most likely in the vertical deflection circuits.
- Loss of horizontal deflection is indicated when the video display has no width; thus, the problem will probably be located in the horizontal deflection circuits.
- An unstable display usually indicates a lack of triggering pulses. The trigger pulses may be derived either internally or externally, depending upon which mode of operation is being used. When the trigger pulses are derived externally, the problem is probably a defective test lead. If the trigger pulses are derived internally, the trouble is probably in the 1000-kc oscillator circuit.
- When no video display is visible, the usual cause is a failure in a video amplifier circuit or defective test lead.
- Loss of operating voltages indicates a failure of the power supply or line fuse.

4-21. Remember that substitution is the best means of determining if the test equipment or the unit being tested has failed.

4-22. *Video sweep generator.* Video sweep generator problems usually consist of no output or an unstable output. Either of these conditions can be checked with an oscilloscope.

- When there is no output from the video sweep generator, the cause may be in any one of several areas: power supply, oscillator, amplifiers, or test leads.
- An unstable output is usually caused by the failure of a component in the oscillator circuit.

4-23 *Multiburst generator.* Since the multiburst generator is a type of signal generator, its output can be checked, or monitored, with an oscilloscope. If any portion of the output waveform is missing or distorted, determine which circuits are concerned, then troubleshoot.

4-24. *Grating generator.* The most noticeable problems occurring in the grating generator are the loss of horizontal bars or vertical bars.

- The loss of the vertical bars indicates a failure of the 15 times multiplier or adder circuits.
- The loss of the horizontal bars indicates a failure of the 20 times multiplier or adder circuits.

4-25. *Dot generator.* A possible problem in the dot generator is the appearance of horizontal or vertical bars. This indicates a failure of the clipper circuit or misadjustment of the clipper bias.

4-26. *Color bar generator.* The color bar generator produces a series of rectangular pulses, red, blue, green, special "I," special "Q," and white, used for color quality testing. The best method of detecting discrepancies is to observe the output on a color monitor. A failure in one of the color bar generator circuits will cause associated problems in the output. Since the color bar generator produces pulses, an oscilloscope can be easily used to trace the pulses through their associated signal paths.

4-27. The most common problem encountered in the color bar generator is low amplitude of the individual pulses. This problem may be caused by a defective amplifier circuit.

4-28. *Vectorscope.* The vectorscope's operation is much like that of an oscilloscope and any problems encountered in it will be similar to those found in the oscilloscope or waveform monitor.

4-29. *Color signal analyzer.* Indications of problems in the color signal analyzer are inability to demodulate the color subcarrier signal or an inability to check the phasing of the color subcarrier.

- When you are unable to demodulate the color subcarrier signal, the malfunction will probably be in the demodulating circuits. Using normal troubleshooting procedures, the circuit malfunction can be rapidly located.
- Phasing problems will be found in the associated phasing network or circuit.

4-30. *Monoscope amplifier (camera).* The failures encountered in a monoscope amplifier (camera) are similar to those found in a simple closed-circuit television camera chain; therefore, the trouble symptoms are also similar. The one major difference between the monoscope amplifier (camera) and other types of television cameras is the pickup tube design, as you know from Volume 2. Because the image is etched on the target of the monoscope tube, defects in the coating material will cause errors in the output video signal.

4-31. **Alternate Quality Testing Methods.** When the test equipment fails, an alternate means of testing system frequency response, picture quality, and color fidelity is necessary. Some of the alternate testing methods may not be as accurate or complete, while others may be more complex than the desired methods. They are, however, acceptable on a temporary basis.

4-32. *Frequency response.* The two items of test equipment generally used for checking and adjusting the television system frequency response are the video sweep generator and the multiburst generator. The video sweep generator, as you know, is used to check and adjust individual circuits and system components; whereas, the multiburst generator is designed to check the overall system frequency response.

4-33. Should the multiburst generator fail, the monoscope amplifier (camera) unit or the EIA resolution chart may be used to check the overall system frequency response. The frequency response checks are accomplished in the same manner when either of these alternate methods becomes necessary. However, you must insure that the camera is properly positioned and focused on the EIA resolution chart when it is used. This is not necessary when the monoscope unit is used since its display is permanently positioned.

4-34. When the EIA resolution pattern is used for frequency response checks, spurious peaks or sharp cutoff of the characteristic response frequency will disclose themselves as irregularities in the video presentation. The irregularities appear as closely spaced, horizontally displaced, positive or negative, delayed or advanced repetitions of the original signal and will appear in the video output of the television system. These discrepancies are called "ringing". The vertical wedges in the pattern are used to determine horizontal resolution. The point in the wedges where the lines appear to blend together indicates the limits of resolution. By referring to the calibration adjacent to the bars, the resolution may be read directly in terms of lines. The maximum horizontal resolution is approximately 80 lines per megahertz of bandwidth. To obtain horizontal resolution in terms of bandwidth, divide the number of lines by 80. To evaluate the frequency response of the system, compare the bandwidth figure obtained with the normal bandwidth figure of the system.

4-35. *Picture quality.* Again, the monoscope amplifier (camera) unit as well as the EIA resolution test patterns are used as an alternate method of testing the overall picture quality of a television system. In addition, the EIA linearity test chart can be used to test the deflection linearity, which in turn will determine the quality of the video signal.

4-36. Since the monoscope camera and EIA resolution patterns are similar, their picture testing capabilities are much the same. As previously discussed (Volume 2), most aspects of the video signal can be analyzed and adjusted while using either of these patterns as a standard. The components of the video signal that may be checked with these patterns are: gray-scale rendition, shading, uniformity, streaking, interlace, aspect ratio, geometric distortion, horizontal and vertical resolution, and irregularities in the response frequency characteristic. All of these items will have specific relations to the picture quality.

4-37. The grating generator pattern may also be considered a picture quality check since it is a check of the deflection linearity. However, it is normally used in addition to the EIA linearity test chart.

4-38. *Color fidelity.* All of the items discussed in the picture quality and frequency response areas will have a determining effect on the color quality. One of the most important things in color reproduction is to first derive a good black and white picture. In addition, other specialized testing procedures have been developed to produce the best quality color picture possible.

4-39. As you know from previous discussion of specialized test equipment (Volume 2), both the vectorscope and color signal analyzer are used as a method of testing the color subcarrier phasing and amplitude. Thus, they may be considered as alternate methods for each other when color subcarrier phase and amplitude tests are required. Likewise, the grating generator and dot generator may be considered as alternate methods of testing convergence of a color receiver.

4-40. The color bar generator produces a series of pulses which, when vectorially added, produce color bars covering the color spectrum. These bars are then used to test the system's ability to reproduce those colors. An alternate means of checking color fidelity is by observing a video presentation. Look for proper shading and color fringing around objects. These will give some indication of the color quality and proper camera setup.

4-41. **Transistor Checks.** The usual troubleshooting practices also apply to transistors. It is recommended that transistor checkers be used to evaluate transistors whenever possible. However, if a transistor tester is not available, a good ohmmeter may be used for this purpose. The ohmmeter selected must, however, meet established requirements since damage to transistors may result when improper test equipment is used. The damage is usually the result of accidentally applying too much current or voltage to the transistor.

4-42. *Test equipment.* Test equipment with a transformerless power supply is one source of excess current. This type of test equipment can be used by employing an isolation transformer in the power line. Damage to the transistor may also result from too much line current, even though the test equipment has a power transformer in the power supply, if the test equipment has a line filter. This filter may act as a voltage divider and apply half of the line voltage and a portion of the line current to the transistor. To eliminate this trouble situation, connect a ground wire from the chassis of the test equipment to the chassis of the equipment under test before making any other connections.

4-43. Another cause of transistor damage is a multimeter that requires excessive current for adequate indications. Multimeters that have sensitivities of less than 5000 ohms per volt should not be used. A multimeter with lower sensitivity will draw too much current through many types of transistors and damage them. The use of 20,000-ohm-per-volt meters or vacuum-tube voltmeters is recommended. Check the ohmmeter circuits (even those in VTVM's) on all scales with an external, low-resistance milliammeter in series with the ohmmeter leads. If the ohmmeter draws more than 1 milliampere on any range, this range cannot be used safely on small transistors.

4-44. Finally, always use fresh batteries of the proper value for the equipment under test. Never use battery eliminators because the regulation of these devices is poor at the current values drawn by transistor circuits. Be certain about identification of polarity before attaching the battery to the equipment under test; polarity reversal may damage the transistor.

4-45. When troubleshooting transistor circuits, be sure the test probes are clean and sharp. Many of the resistors used in transistorized equipment have low values; therefore any additional resistance produced by a dirty test probe will make a good resistor appear to be out of tolerance.

4-46. *Ohmmeter test of transistors.* To check a p-n-p transistor, connect the positive lead of the ohmmeter to the base and the negative lead to the emitter. Use caution when connecting the test leads to the transistor, since the red lead is not necessarily the positive lead on all ohmmeters. Generally, a resistance reading of 50,000 ohms or more should be obtained. Connect the negative lead to the collector; again a reading of 50,000 ohms or more should be obtained. Reconnect the circuit with the negative lead of the ohmmeter to the base. With the positive lead connected to the emitter, a value of resistance of approximately 500 ohms or less should be obtained. Likewise, with the positive lead connected to the collector, a value of 500 ohms or less should be obtained.

4-47. Similar tests on n-p-n transistors will produce the following results. With the negative ohmmeter test lead connected to the base and the positive test lead connected to the emitter, the value of resistance should be high. Then connect the positive test lead to the collector; the value of the resistance should again be high. With the positive ohmmeter test lead connected to the base and the negative test lead connected to the emitter, the value of the resistance between the base and emitter should be low. Likewise, when the negative test lead is connected to the collector the value of the resistance should be low.

4-48. If the readings in either instance do not check out as indicated, the transistor is probably defective and should be replaced. If a defective transistor is found, make sure that the cricuit is in good operating order before inserting the replacement transistor. If a short circuit exists in the circuit, plugging in another transistor most likely will result in another burned-out transistor. Do not depend upon fuses to protect transistors. The transistor is very sensitive to improper bias voltages; therefore, a short or open circuit in the bias resistors may damage the transistor. For this reason, do not troubleshoot by shorting various points in the circuit to ground and listening for clicks.

5. Troubleshooting and Maintenance Procedures

5-1. In this section we will outline systematic troubleshooting procedures and identify what each step entails. A description of how intricate alignment, calibration, and maintenance procedures are written and used is included with a few examples. Finally we will propose some courses of action to take should you be faced with recurring equipment malfunctions.

5-2. **Elements of Troubleshooting and Repair.** When troubleshooting a television system, there are basic steps which should be followed. These steps should be accomplished in a systematic sequence such as: symptom recognition, symptom analysis, trouble localization, trouble analysis, and trouble correction. In the following paragraphs we will discuss each of these steps and enumerate the things to be considered as the troubleshooting process develops.

5-3. *Symptom recognition.* The symptom may be defined as a trouble indication. Some examples of symptoms are: no video, no raster, unstable synchronization, weak picture, and any other indication of trouble in the television system. Most trouble symptoms indicate malfunctions in either the transmission or receiving equipments. As an example, unstable synchronization can be a symptom of trouble in the synchronizing generator, pulse distribution amplifier, video distribution amplifier, video transmitter, or receiver. Once you have detected a trouble from a particular symptom, analyze that symptom.

5-4. *Symptom analysis.* Symptom analysis is the process of determining in what area or areas a trouble, with a particular symptom, could originate. Again referring to the symptom of unstable synchronization, analyze that symptom, determine the trouble possibilities, and then isolate the malfunction.

5-5. *Trouble localization.* After determining the possible troubles, through symptom analysis, isolate the malfunction using systematic troubleshooting procedures. Where the symptom indicates that the trouble may originate in either the transmission or receiving equipment, isolate the problem to one or the other. In either area, the trouble can be further localized through signal tracing. When the failed unit is located, a combination of signal tracing, voltage readings, and resistance measurements may be used to isolate the faulty circuit and finally the failed component.

5-6. *Trouble analysis.* When the malfunctioning unit is located, an analysis of the trouble may indicate which circuit has failed. An analysis of the signal at various points in the unit will indicate possible circuit and component failures. Thus, trouble analysis is the process of evaluating signal discrepancies and relating them to possible circuit malfunctions.

5-7. *Trouble correction.* When the failed circuit component has been located, the final step of correction is necessary. At this point, complete any disassembly, replacement, repair, and reassembly deemed necessary to place the equipment in proper operating condition.

5-8. **Recurring Malfunction Correction.** Usually, malfunctions that recur regularly indicate one of two things: another faulty component or circuit which is causing the more obvious problem or faulty design of the malfunctioning circuit. Correction of the recurring malfunction demands that you locate the basic cause of the problem. If the cause is another faulty component or circuit, simply replace or repair that item. However, if the recurring malfunction is caused by faulty circuit design, recommendations for modification of that circuit will be necessary.

5-9. **Prescribed Maintenance Procedures.** All prescribed maintenance procedures should be written in a logical sequence. Maintenance procedures are written and used to eliminate the possibility of forgetting to accomplish assigned tasks. Failure to complete a specified task may result in an operational malfunction. Preventive maintenance instructions (PMI's), alignment, and calibration procedures are examples of prescribed maintenance procedures.

5-10. *Alignment and calibration procedures.* Alignment and calibration procedures must be accomplished upon installation of all new equipment to insure its proper operation. They must also be performed after replacement of circuit components, after certain system maintenance has been completed, and immediately prior to operation. This last requirement is necessary at least daily, twice daily, and sometimes on a more frequent basis, depending on the type of equipment and the operational requirements of the television system.

5-11. Examples of transmission equipment alignment and calibration requirements are camera setup, synchronizing generator adjustments, pulse and video distribution amplifier gain adjustments, audio output checks, and transmitter tuning. In addition, color transmission alignment and calibration procedures will include the colorplexer setup, a more detailed camera setup, and the alignment of other units as necessary for proper color production.

5-12. The most common alignment procedures performed on color television receivers and monitors are convergence, purity, and white balance (temperature adjustments). These procedures may need to be accomplished each time the components affecting their circuit operation are replaced.

5-13. *Written alignment and calibration procedures.* Alignment and calibration procedures should be written in a straightforward, logical sequence of events. Consequently, the steps are written in such a manner that even the most complex alignment and calibration procedures can be easily followed. An example of some of the more complex procedures are those required for adjusting convergence, purity, and temperature of a color television receiver.

6. Systematic Repair

6-1. In this section we will discuss the practices, procedures, and precautions necessary to perform logical and systematic repair of television equipment. The advantages of using bench mockups for television equipment checkout and alignment will also be identified and compared to alternate checkout procedures. Finally, we will specify the responsibilities for repair, calibration, and certification of various categories of precision measuring equipment.

6-2. **Equipment Repair.** In order to repair television equipment there are four necessary functions—disassembly, replacement, repair, and reassembly—which must be done. There are also certain procedures, practices, and precautions which must be observed and followed when you do these tasks. We now describe the procedures, practices, and precautions as they relate to the four repair tasks.

6-3. *Disassembly.* During disassembly of television equipment it is most important that you follow the recommended procedures contained in the appropriate technical order or manufacturer's handbook. If no disassembly instructions are available, proceed with the most direct approach, taking care not to disassemble any more than necessary in this phase of the equipment repair. While disassembling the equipment, place all component parts, in orderly fashion, in a clean and convenient location. Place all small components, nuts, and bolts in containers. This will prevent the parts from being scattered and lost. Soldered and other types of mechanical wiring connections should be labeled during disassembly. Labeling will permit their proper reconnection during reassembly.

6-4. *Replacement.* This action is necessary when the malfunctioning component requires replacement. When replacing parts, insure that only like items or suitable substitutes are used to replace circuit components. Unsuitable replacement parts may do further damage to that equipment or other equipment in the television system.

6-5. If solder connections are used, insure that they are properly made; cold-solder joints and loose connections will decrease the equipment's operating capabilities.

6-6. *Repair.* If it is possible to repair the failed component without decreasing the equipment operating efficiency, by all means do so. On the other hand, some breakdowns lend themselves more readily to repair than others. Failures such as broken connections, cold-solder joints, and other similar defects should be repaired rather than replaced. When dealing with broken connections, consult schematic and wiring diagrams if there is any doubt about where the connection should be made. Failure to consult the necessary diagrams, and a resulting wrong connection, may cause serious damage to the equipment and the rest of the television system serviced by that equipment.

6-7. *Reassembly*. Remember that reassembly is simply the reverse operation of the diassembly task; however, you must insure that all parts and components are replaced in their original positions. Care must also be exercised when replacing such items as screws, nuts, and bolts; be sure that they are not cross threaded or otherwise damaged during reassembly. All electrical connections must be replaced in their proper place and good solder connections made when appropriate. A final visual check of the equipment should be made to insure that no shorts, broken wires, loose solder, washers, or other discrepances are found before returning the equipment to operation.

6-8. **Advantages of Bench Mockups.** There are many advantages in using bench mockups and their related test equipment for final checkout of television equipment. Bench mockups facilitate alignment, calibrating, and final checkout procedures before the equipment is installed or reinstalled in the television system. Consequently, the equipment is known to be in good operating condition prior to use. Since bench mockups are permanently set up, they are available for prompt equipment checkout at all times. Therefore, spare equipment can be readily maintained in good operating condition and placed in operation at a moment's notice if needed.

6-9. **Alternate Checkout Methods.** When bench mockups are not available, the equipment must be checked with test equipment similar to that used in bench mockups or placed in an operational facility for final checkout, alignment, and calibration. These alternate testing methods create some disadvantages. The test equipment must be set up each time it is used, and the operating facility is not always available due to scheduled programming. Consequently, delays and increased time outages may be encountered.

6-10. **Quality Checks.** Quality checks are final inspections to insure that the equipment is in acceptable condition prior to being placed in operation. The quality inspector must make sure that all repairs were completed and had met the highest standards. Any defects found should be noted and brought to the attention of those responsible, as this could be a basis for additional training. This may also require reaccomplishment of the repair task; poor workmanship could cause damage to other system equipment and extended outage of the system.

6-11. **Precision Measuring Equipment (PME).** Precision measuring equipment consists of tools and test equipment required for repair, inspection, calibration, or adjustment of operating equipment, major assembly, or components, whose normal function is to measure or provide a known reference of comparison for performance characteristics.

6-12. *PME categories*. PME categories are established to identify system, subsystem, and equipment calibration requirements, and to facilitate assignment of responsibility for calibration, certification, and repair.

6-13. Category 1 equipment is operational equipment installed in systems, subsystems, or equipment whose performance parameters are to be measured, verified, or tested

6-14. Category 2 equipment is peculiar PME used to check, maintain, and calibrate category 1 equipment.

6-15. Category 3 equipment is commercial and military standard PME used for maintenance, troubleshooting, testing, verification, and calibration of category 1 and 2 equipment.

6-16. Category 4 equipment consists of standards and accessories used to calibrate category 2 and 3 equipment.

6-17. *Calibration and certification of PME*. Calibration is a comparison between instruments; one is a standard of known accuracy used to detect and correlate or adjust any variation in the accuracy of the instrument being compared.

6-18. Certification is the act of designating that the PME has been calibrated and meets the established standards.

6-19. Economy, mission, and combat effectiveness demand that maximum calibration be performed at the lowest practical organizational element. Maximum emphasis must be placed at all levels on fast, high-quality, base-level support and TO compliance. The calibration and certification of PME are performed as prescribed in the TO 33K series calibration procedures.

6-20. The maximum interval for recalibration of PME is specified in TO 33K–1–01 except for those intervals prescribed in Calibration Measurement Summaries for PME, as applied to a specific system. Calibration intervals prescribed in Calibration Measurement Summaries take precedence over all other TO's. Items designated "schedule calibration as necessary" (SCAN) will normally be recalibrated at unscheduled intervals unless the using organization elects to establish a scheduled interval based on system application. When an interval or SCAN is not prescribed in TO 33K–1–01, the maximum calibration interval is 180 days.

6-21. There is no minimum time interval between calibration periods of PME. When it has been determined that PME requires calibration or is known to have been subjected to rough handling, overload, or other conditions detrimental to the capabilities of the equipment, it must be considered questionable. Recalibration of equipment falling into this category is mandatory. PME that has exceeded the prescribed calibration interval or has not been calibrated will not be used.

6-22. PME, especially that of a general-purpose nature, is designed to operate over a wide range. This equipment may be used only over a portion of the range or at certain points in the range. When this is the case, there is no need to certify the entire range. You should calibrate only at the points or in the ranges where used if the calibration range is clearly indicated on the instrument. It is the using activity's responsibility to specify desired calibration points or ranges on AFTO Form 211, Maintenance Discrepancy/Production Credit Record.

6-23. PME having ancillary equipment such as cables, probes, test leads, and other accessory components must be delivered to the Precision Measuring Equipment Laboratory (PMEL) in a complete package. The PMEL may return without action any item that is not sufficiently complete to allow full calibration and certification.

6-24. At installations where AF standards are not maintained, PME is calibrated by the closest PMEL subject to support agreements negotiated between the site or base and the supporting activity. Remote sites and bases are required to investigate this type of calibration support prior to requesting command van assistance.

6-25. Items in storage do not require periodic calibration. Items which are overdue for calibration may be shipped as serviceable. Activities receiving such items should have the responsible PMEL calibrate them before placing the items in use.

6-26. Activities involved in evaluation of techniques and procedures or collection of data for prototype calibration equipment may not have requirements for scheduled periodic calibration of its PME. These equipments may be identified with an AFTO Form 108, Certification Label, marked "this equipment is used for _____ and need not be periodically calibrated." The AFTO Form 108 must be signed and dated by the owning organization supervisor. In the event equipment status changes, it is to revert back to a periodic calibration schedule. Under no circumstances will PME being used to determine serviceability or acceptability of systems or other equipments be released from the requirement of periodic calibration.

6-27. *Calibration and certification responsibilities.* The basic requirements and assignment of responsibilities for calibration and certification of PME are outlined in AFR 74-2, *Repair, Calibration, and Certification of Precision Measurement Equipment.* This regulation is applicable to all personnel engaged on organizational-, field-, and depot-level maintenance of Air Force precision measuring equipment.

6-28. The PMEL, established in accordance with AFR 74-2 as the base focal point in the AF single integrated calibration system, will be responsible for:

- Operating and maintaining the highest echelon of calibration reference standards assigned to the base.
- The calibration and certification of category 3 general-purpose AF and commercial test equipment.
- The calibration and certification of general-purpose AF and commercial test equipment used as component parts of category 2 equipment which does not require calibration in place and can be removed to the PMEL for the work to be accomplished.
- Participating with other base-assigned or tenant activities in calibration of category 1 and 2 equipment that must be calibrated in place and which requires skills or equipment available only at the base PMEL. Base reference standards will not be removed from the PMEL for this purpose.
- Calibration and certification of selected category 2 items specifically identified in TO 33K-1-01.

6-29. In addition to responsibilities for normal maintenance, activities having responsibility for maintenance of weapon and support systems and equipment will be responsible for:

- Calibration of category 1 and 2 equipment and certification of category 3 equipment.
- Return of AF and commercial general-purpose test equipment, including any category 4-type items in their possession, to the base PMEL on a scheduled basis for calibration.
- Requesting assistance from the base PMEL on category 1 and 2 items on which such assistance is specified in the applicable 33K series weapon system TO.
- Requesting command assistance through channels for calibration of category 2 equipment beyond the base PMEL resource capability.

6-30. Any category 1 and 2 items on which the PMEL has participating responsibility for calibration will be identified during the weapon system calibration review and indicated in the applicable 33K series TO.

6-31. Those types of category 4 equipment authorized to activities other than the base PMEL which are used for support of advanced systems and equipment are referred to the base PMEL for calibration. The base PMEL will either calibrate or will have these devices calibrated by an echelon capable of meeting the required accuracy.

6-32. While the above responsibiilties are directed generally to system support where categories can be readily determined, the same principles can be applied to "nonsystem" equipment.

6-33. Calibration responsibilities for specific items of equipment are published in TO 33K-1-01 and the system calibration measurement summary. Activities requiring clarification of equipment categories and calibration responsibilities not listed in these TO's should submit their requirements to the Calibration and Meteorology Division.

6-34. The using organization is responsible for compiling an accurate list of all tools and equipment which require calibration, inspection, or adjustment by PMEL or the calibrating work center. This list will be used by Data Systems to establish the PME scheduling master file. The using organization will also notify Data Systems whenever the owning work center, building number, or phone number used to identify the location of equipment is changed. This is necessary in order for Data Systems to prepare accurate scheduling reports.

6-35. It is the responsibility of the using organization to process a new item of equipment through the PMEL or calibrating work center to verify calibration of the item. This action is taken in accordance with procedures established for scheduled calibration. The input forms will serve to establish a scheduling card for the master file to control future calibrations.

6-36. The organizational equipment custodian will be responsible for immediately notifying the PMEL or calibrating work center of all changes (quantity, serial number, etc.) to the inventory if manual instead of mechanized records are maintained.

6-37. The AFTO Form 211 initiated by the owning organization must contain the following entries.

a. The owning organization will enter the Federal Supply Class Code for the item in block 1c.

b. The owning activity will enter the part number for the item as listed on the data plate or in the parts catalog in block 2c. If an item does not have a part number, the manufacturer's model number will be recorded in this block. If the item has neither a part number nor a model number, the Federal Item Identification Number, which consists of all digits following the Federal stock class, will be recorded in this space.

c. The owning activity will enter the manufacturer's or AF serial number in block 3c. If no manufacturer's or AF serial number is assigned, a local number will be assigned by the PMEL or calibrating work center and this number will be used as long as the equipment is assigned to the base. Locally assigned serial numbers will not exceed eight digits.

d. The PMEL or calibrating work center technician or the owing organization will enter the appropriate "when discovered" code from TO 00-25-06-4-1, *Field Maintenance Shops Work Unit Code Manual, Precision measuring Equipment*, or TO 00-25-06-2-2, *Field Maintenance Instructions, Work Unit Code Manual, Aerospace Ground Equipment*, that identifies scheduled or unscheduled calibration or repair of the equipment being processed. This information is entered in block 9 of AF Form 211.

e. The owning activity will enter a brief description of the work required in block K.

f. The owning activity will enter the work center code, building number where the equipment is located, and the phone number of the responsible office in that order. This information is recorded in Block L of AFTO Form 211.

6-38. All four copies of the AFTO Form 211 will be attached to the item by the owning activity before it is delivered to the PMEL or calibrating work center workload scheduler. Upon receipt, copy 1 of the form will be signed by the scheduler and dated in the last line of block K. Copy 1 of the AFTO Form 211 will then serve as a receipt by the owning organization.

6-39. When the necessary action has been completed on the PME and the workload scheduler has properly completed the forms, the equipment will be returned to the using activity. The workload scheduler will obtain the AFTO Form 211, copy 1, at this time and destroy it.

CHAPTER 3

Diagnosing System Troubles

IF THE TV equipment and systems are to operate in accordance with applicable specifications, you must maintain the equipment and systems to meet certain standards. In this chapter we will discuss some of the procedures for diagnosing system troubles and the general manner in which diagnosis is accomplished. The following system troubles are not intended to familiarize you with one specific system, but rather to acquaint you with the general nature of all systems. In addition to discussing a number of troubles, we will discuss symptoms of troubles, symptom analysis, and associated circuit performance.

2. Troubles of the transmission system will be discussed first and the receiving system last in this chapter. However, remember there will be interrelated symptoms. Yet, with cumulative experience, it will become easier to recognize in which of the systems or unit of a system a trouble exists. The major units of the transmission system where problems can arise are power supply, sync generator, camera, switcher, distribution amplifiers, monitor, exciter, and transmitting antenna. The major units of the receiving system are subdivided into two groups; however, this is only an arbitrary subdivision as other combinations are possible. For our purposes we will divide the receiving equipment in the following manner: antenna, cable, and receiver; tape machine, distribution amplifiers, and monitor.

3. To communicate by television, we need only a few items of equipment. However, if equipment problems are studied in a complete system, you will be able to understand these problems in a simple system. The symptoms presented and reasoning used to locate the unit at fault are intended to help you become proficient in diagnosing system troubles. The symptoms and problems form a pattern for diagnosing system troubles, which may be similar or different, yet the analysis process is the same.

7. Transmission System Troubles

7-1. We must be able to eliminate either the transmitting system or receiving system as the first step toward locating the trouble. We should be able to recognize interference due to spurious signals, ghost signals, adjacent channel or cochannel signals, and local oscillators which are radiating signals, plus many more signal sources. Incidentally, these interfering signals may be present in both cable and radiated systems. In system maintenance when we are locating transmission system trouble, we would, in a sense, use a split system analysis. In a radiated system, for example, we would simply select another channel to determine if the receiver was functioning properly. In cable broadcast we could do the same; however, in most closed circuit systems, we would only need to feed in a test signal from installed test equipment. In any case, after insuring that the receiver is working properly, we assume the transmission system to be faulty. When the preliminary analysis is completed and the transmission system is found to be at fault, the ensuing steps are to locate and repair the trouble or troubles.

7-2. The following troubleshooting and trouble analysis procedures for a television system are based upon system operation. Faults can be isolated, to some extent, during preliminary test setup operations by observing the results of these operations on the viewer monitors and the maintenance monitor. Normally, operating units can be eliminated as a source of trouble by switching between cameras and monitors and observing all units before starting trouble analysis of the system. For example, a malfunction in one of the camera units could indicate a possible trouble in the monitor, the switching and distribution circuits, or the camera. By switching the monitor to use another camera, the monitor and the switching and distribution circuits are eliminated as the cause of trouble.

7-3. The procedures in this section are limited to diagnosing troubles of a complete system because you have already studied troubleshooting and trouble analysis of the individual units in the system. In some instances a reverse procedure is used; that is, the trouble is given for a unit of the system. The following discussion concerns the symptoms as they appear throughout the system.

7-4. **Power Supply.** In our first example we will take a known trouble and list the symptoms which will be found throughout the system. Remember, this is a principle-centered study and not a specific power supply. Assume you have a power supply which provides unregulated voltages, regulated voltage, and centering current. We will assume that the unregulated output voltages and the centering current are normal, but the regulated voltage output is zero. In some instances this trouble can be found by a voltage check with the meter built into the power supply. In other cases it will be necessary to find the trouble through analysis of the equipment symptoms, which would require verification by the use of an external meter at checkpoints.

7-5. When there is a failure of the regulated voltage output, the symptoms would be raster only on utility monitor and camera control monitor; the camera view finder will not have a raster, and the waveform monitor will have a trace line without any video modulation. However, these symptoms could also be present in a camera control unit which uses a free-running oscillator driven by the sync generator. For example, if the sync generator drive failed, you would lose the oscillator output and thus the signal.

7-6. A note of caution when looking at the reverse of the preceding analysis symptoms: Never grasp at a quick conclusion when an image disappears from a screen. With the disappearance of an image on one monitor or viewfinder, cross-check with other monitors. If the presentation is from a live camera and it is in a closed circuit system, there will probably be a voice circuit to aid in making the suggested checks. if the presentation is from a taped source, there will be a monitor on the tape machine or in the tape room, thus enabling cross-checks with the initiating point.

7-7. Again referring to the power supply as a source of trouble, you can examine the symptoms for a clue to the actual power supply trouble. As previously stated, you do not have regulated voltage; therefore, there is no image pickup but there is a raster on camera control monitor. This indicates there is some high voltage present; thus, it can be assumed that the control relay of the power supply is functioning. On the other hand, if you do not have any voltage present, you would assume that a relay could be at fault. Most power supplies are equipped with time-delay devices to permit adequate warmup time. If the time-delay device (relay) should fail, this will eliminate the various output voltages, and it will also eliminate any centering current output. The exact nature of the trouble as to its symptoms will also depend on the power supply itself. If the heating element of the tie delay is open, then the pilot light probably will not light. If the fuse is blown, this will give the same indication. Through this reasoning you will probably check the fuse and pilot light before checking the time-delay relay. Again, it is a matter of reading the symptoms correctly and being able to make a quick diagnosis of the possible troubles. Consequently, a faster repair can be made and the system will be returned sooner to operational status.

7-8. **Sync Generator.** Assume that you have a closed circuit system in which the monitor in your room is tearing horizontally. This is not the even displacement, such as the venetian blind effect, but represents the loss of scanning lines or portions of lines anywhere in the picture due to something which affects synchronization. Normally, your first assumption is that the horizontal oscillator of the monitor in question is not operating properly. Again, it is important that a cross-check with other monitors be made where possible. If a cross-check is not possible, then a check with monitors at the point of origin of the signal is the next step. A check in this instance reveals that all monitors are giving the same indications of tearing.

7-9. If, in a given instance, a cross-check did not give the same indications but rather only one set had the indications and this was connected to only one distribution amplifier, then you would check the distribution amplifier or the monitor. A substitution of a distribution amplifier or another monitor would localize the trouble to the given unit of a system.

7-10. Going back to the original set of symptoms, cross-check with other sets, and then proceed on to the sync generator. Here you again substitute, if possible, to localize to the sync generator. If you do not have a spare sync generator, you would probably use a scope to check the 15,750 signal. If this signal is not stable, you will find the symptoms as indicated. Another method of checking frequency stability is to use a frequency counter with a short-time constant, since it will indicate the frequency drift by recounting the frequency each time it changes.

7-11. **Camera.** In this instance, assume the situation of a live camera presentation with a number of monitors in use simultaneously. The following symptoms appear: you have a normal picture and the presentation is normal; suddenly the normal presentation is interrupted and there is only a raster on the monitor in question. Immediately a cross-check is made to determine if the same indications are to be found on other monitors. In this instance all monitors are the same; that is, a raster but no picture. After a cross-check of monitors, a check to see if the camera has an output is in order. The next logical step is to use a substitute camera to make the final determination of a faulty camera.

7-12. Another camera trouble which happens quite frequently is the (white) high-peaker adjustment. The symptoms of this trouble are white streaks to the right of an object as it appears on the monitor screen. When this symptom appears, and if a cross-check is made, the same indications will appear on the other monitors. A substitute camera should eliminate this trouble, unless the second camera would have the same trouble (which is unlikely). The actual trouble in the camera is the high-frequency compensators out of adjustment. This trouble can usually be corrected by adjusting the high-peaker control while observing the monitor screen.

7-13. There is another very similar trouble which occurs in the black regions of the signal. Since this is in the dark portions of the picture, it is not so noticeable. The dark streaking will be most noticeable when a test pattern is being picked up by the camera. The blacks will have trailing streaks to their right as observed on the monitor screen. This can be adjusted by changing the setting of the low-frequency peaking control, while observing the monitor screen. When a major realignment of these circuits is necessary, a sweep generator and a scope must be used to obtain the correct envelope presentations.

7-14. **Switcher.** A symptom which will appear as a result of faulty switcher contacts is a loss of sync. This will be evidenced by the vertical roll and the horizontal flopover of the picture. These symptoms may appear together or individually. This trouble can be quickly checked on a live program by checking the line monitor at the immediate output of the switcher. The line monitor compared to the camera-ready monitors and preview monitors will immediately localize the trouble to the switcher.

7-15. Another trouble which will be evident to the switcher operator is the loss of picture after punch up. This is where there is a picture while the switcher button is pushed down; but when the button is released, the picture on the line monitor disappears. This is a fault in the switch buttons of the switcher panel. These troubles may be further localized by punching up another camera to cross-check with another selecter button on the switcher control panel. In this way the trouble may be localized to the exact pushbutton at fault. Use an oscilloscope to circuit trace in the switcher when locating the exact set of contacts at fault, or in some cases the relay at fault.

7-16. **Distribution Amplifiers.** There are two basic types of distribution amplifiers: the pulse distribution amplifiers and the video distribution amplifiers. They are similar in their construction and use; however, the pulse distribution amplifier is designed to handle more power than the video distribution amplifier. The pulse distribution amplifier also has more adjustments; thus it is set up in a different manner. These two basic types are not to be interchanged in an installation. If they are inadvertently interchanged during installation, there will be problems in the initial adjustments of the system. If during checkout of a new system this difficulty of adjustment is experienced by personnel, the first items to look at would be the distribution amplifiers to see if the correct units are installed.

7-17. *Pulse distribution amplifiers.* The pulse distribution amplifiers can be responsible for a number of symptoms in a live camera system. Individual pulse distribution amplifiers can be responsible for loss of sync pulses, vertical drive pulses, horizontal drive pulses, and blanking pulses. This would be indicated by failure of the respective picture elements as they appear on a monitor screen. Another factor is the actual system location of the pulse distribution amplifier; this location will determine the overall effect and symptom indication.

7-18. Assume that the system is a live camera presentation and suddenly the picture disappears on a room monitor. Immediately upon making a cross-check of other monitors in the system, you find there are no images on any monitors, but there are rasters present. However, when the monitor on the camera (view finder) is checked it does not have a raster. This symptom could be an indication of a failure of either the vertical or horizontal sweep signal. The failure of either of these signals will result in the activation of the camera protection circuit to prevent burning of the camera tube or the picture tube. Since there are separate pulse distribution amplifiers used to drive the horizontal and the vertical sweep, it can be concluded that a failure of either of these distribution amplifiers would cause the system to give the indicated symptoms.

7-19. As you will recall, there is also a separate pulse distribution amplifier for the blanking pluse. Consequently, if this distribution amplifier fails, then the blanking pulses would not be present to eliminate the retrace lines. Thus, in the picture presentation there would be retrace lines visible on the system monitors. A word of caution—in some monitors if the brightness is incorrectly adjusted, retrace lines may also be visible. This emphasizes the value of making a cross-check with other monitor units of the system.

7-20. If the pulse distribution amplifier which is used for the sync pulse fails, then there will be a loss of both vertical and horizontal sync. This is evidenced by vertical roll or horizontal flopover in the video presentation. Since individual monitors in many cases have adjustments for this, it is important that a cross-check with other sets be made before any conclusions are drawn.

7-21. *Video distribution amplifiers.* The video distribution amplifier is designed to pass either the blanked video only, composite video, or sync signal. Its actual use depends upon its location in the system. Therefore, any symptom that is to be traced to a video amplifier must be thought of in relation to the amplifier's location. If it is in the system prior to the sync being added, the composite signal will have sync but it will not have video. Suppose you have a loss of composite signal, but on a cross-check you find that the sync and the blanked video signals are present in the system. This combination of symptoms indicates that the distribution amplifier responsible is located in the system following a point at which the composite signal was formed—probably at the switcher output. Most of the system troubles that may be traced to a video distribution amplifier will never occur. Or it can be said, they should not occur because during the preoperational test all normal problems will be recognized and repairs will be made.

7-22. Assume that a tube weakens in a video distribution amplifier used to amplify the composite output signal and a dimming of picture signal is apparent. A cross-check also reveals the identical symptoms on all monitors, including the line monitor in the control room; however, it would not include the preview monitor and the individual camera monitors located along with the line monitor. Again it is the situation of reasoning out the most likely problem from the symptoms presented, and keeping this idea in mind, you will find most of the trouble sources rapidly.

7-23. **Monitor.** Since the monitor is—in a manner of speaking—the end of a system, there will be few troubles inserted into the system from the monitor. The monitor is the termination for each output of the video distribtuion amplifiers.

7-24. Assume there is a sudden loss of signal at a particular monitor. With a cross-check you find there is a signal present at the other monitors connected to the same video distribution amplifier. The distribution amplifier would not be at fault in this instance unless there was an open in the output for the specific monitor. Now if you have the symptom of no signal at a monitor, and on a cross-check you find there is no signal at the associated monitors connected to the same video distribution amplifier, the first suspected fault would be the video distribution amplifier.

7-25. **Exciter.** The term "exciter" is used to identify the r-f signal generator used in either the cabled closed circuit or the radiated signal system. In the case of the cabled system, with a video r-f carrier, if the exciter were to fail there would be a loss of the video signal. In some of the more elaborate cable systems the exciter is used to generate a carrier for both the video and audio; an exciter failure results in a failure of both video and audio signals. This is assuming that the failure is of a nature that would cause a loss of power to the entire unit. There will be instances where only a tube fails and thus only one signal will be lost.

7-26. Assume the situation of a cabled closed circuit system which uses an r-f carrier for both the video and audio. In this instance it will be rather easy to find the part of the system that is at fault when a failure of the exciter unit occurs. For example, if suddenly the monitor's video image is lost and the audio is good, many possible troubles are eliminated immediately. Reason it this way: If a cable breaks or power failure occurs, all signals will be lost. By making a cross-check, it is determned the other monitors have the same symptoms; therefore, you will know the trouble is at a point in the system common to all monitors. A further check reveals that the line monitor at the input of the exciter modulator section has a video signal present. Thus, all of the sections are eliminated as a source of trouble except the modulator portion and the exciter stages. It is assumed that the r-f carrier is common to both the video and audio stages; therefore if the audio is being received and the video is not, the r-f section of the exciter unit must be good. This would leave the source of trouble as the video modulator portion of the exciter unit.

7-27. If the system being used is of the type which uses an r-f carrier for video, and the audio is transmitted by conventional wire, the technique will be simpler. In this instance, there will only be one signal (video) to be affected by the failure of the exciter. In this case, it will be merely a matter of elimination to determine the point at which the video signal is no longer present.

7-28. The exciter becomes a very important part of the radiated system, both broadcast and relay. In the case of the relay system the exciter can be used as a carrier for the video only or it can be used for a carrier of video and audio. The broadcast system does not use the same exciter for both the video and audio carrier. As you will recall from earlier volumes, the video is AM and the audio is FM.

7-29. This tells us that the relay system will have a complete failure of both signals when one common carrier is used. However, in the instance where the relay system uses a video r-f carrier and the audio is carried by wire, there will be only one signal failure as a result of exciter failure.

7-30. The broadcast system will also experience separate exciter failures. That is, the exicter for video will not affect the one for the audio unless it causes a complete power failure, as would be true in case the audio exciter caused a power failure. Where the exciter units or associated modulator units fail in the broadcast system, it will usually require more extensive troubleshooting to find the source of the trouble. The failure of the video will give more symptoms than the audio because of the fact that it is AM. This means there can be a carrier signal present even though the video modulator fails. This is evidenced by the gray raster but no image is present on the picture tube.

7-31. **Transmitting Antenna.** Transmitting antennas are in two basic categories: the broadcast antenna and the microwave relay antenna. Therefore, there are two basic types of problems as related to the use of the antenna. For example, the broadcast antenna failure will be noted on all receiving sets, whereas in a closed circuit system with a microwave link, a relay antenna failure will be noted only on the closed circuit receiving system. The overall effect of any antenna failure will of course be indicated first on the receiving sets. The indications on the sets will be any variation from a weakening of picture to a complete loss of picture. Also, since the audio carrier is fed in from a separate transmitter in the case of the broadcast unit, there could be a weakening or loss of audio which woud be directly attributable to the antenna system.

7-32. *Broadcast.* In most instances the maintenance personnel will recognize trouble symptoms associated with a broadcast antenna just as quickly as those using receiving sets. There will be instances where those using receivers will notice problems first; however, unless they are trained maintenance personnel, they will not be able to recognize the difference in receiver problems and transmitter problems. If the transmitting antenna becomes damaged or the coaxial cable becomes damaged, there will be an alarm signal. This may be either audible or visual, but it will indicate the failure of the antenna system. Then by analyzing the associated meters, the exact type of failure can be determined. In this type of trouble there is not a great problem in finding the part of the system at fault. It will require more extensive analysis to determine the exact cause of the trouble, but the system has been located and repair action can be initiated.

7-33. *Microwave relay.* The failure of a microwave relay antenna will be more of a go or no-go situation. This is due to the limited power and directivity of the antenna because if power weakens or alignment is changed, there will be no signal. As stated earlier, normally there will be only one receiver unit affected—the microwave receiver. However, the receiver will be connected to a monitor system which may contain one or more monitor units. The monitors will not receive a signal and the video and audio will be lost. Those using the monitors will be aware of a failure but will not know its exact location. Both the microwave receiver and transmitter will alarm when the signal is lost. There is little effort required to locate the system causing the trouble. The problem will be in finding the trouble in the system by using test equipment.

8. Receiving System Troubles

8-1. As already stated, the receiving equipment may be divided into a number of combinations. Also the receiving equipment may be combined into one large system in which all the different types of units are used, even to the

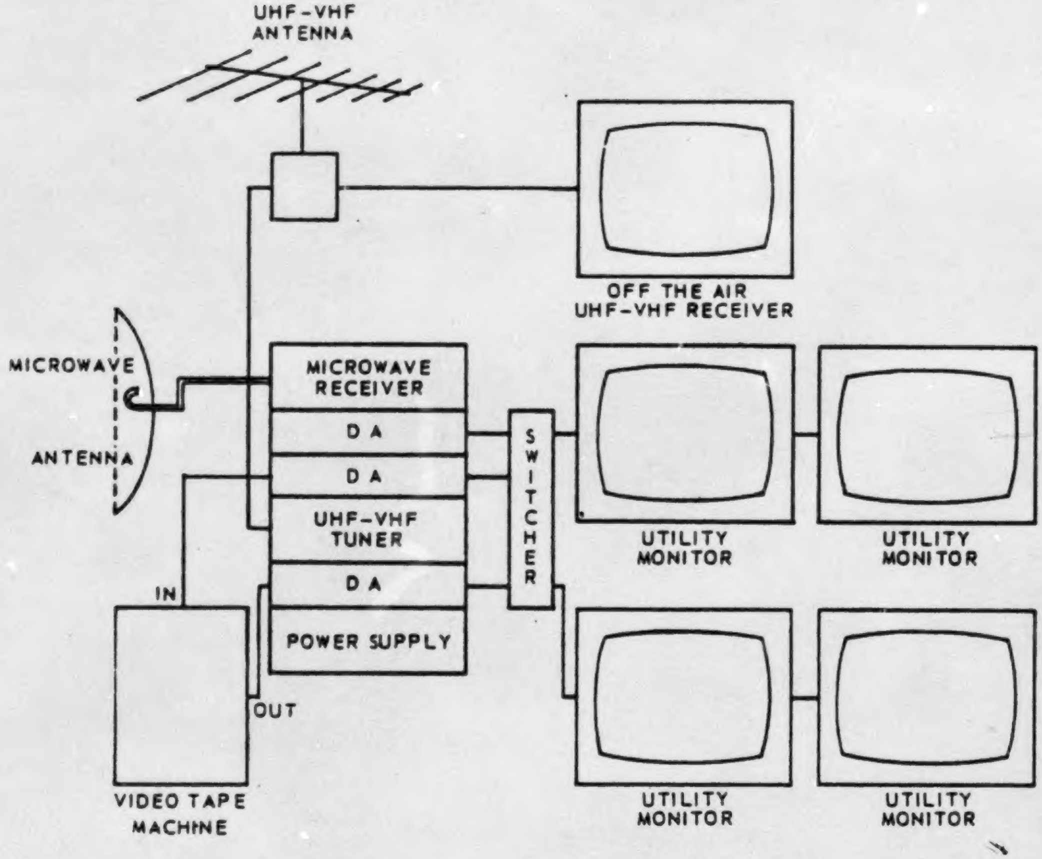

Figure 2. Receiving equipment combinations.

extent of duplicaton of many of the units. As already implied, there will be a large number of monitors or receivers in most systems. Logical reasoning will lead to the conclusion that where the most equipment is involved in a system there will be more system problems. In contrast there will be a minimum number of antennas, cables, tape machines, and distribution amplifiers. Figure 2 illustrates an overall combination of receiving equipment. Any given installation could include part or all of the equipment shown in the illustration.

8-2. **Simple System.** The term "simple system" is used here only as a means of separating systems. The simplest system then includes an antenna, a cable from the antenna to the receiver, and the receiver. In this system if you lose the video and audio, but still have a lighted screen, you would suspect the incoming signal. The quickest check is to change channels. If there still is no signal, the next step is to check the immediate system. This includes the cable connections, the cable, and the antenna. If a visual inspection reveals the connections and cable to be in apparently good condition, the next step is to use test equipment. When more than one receiver is available, substitution of receivers will localize to one specific cable or antenna. In some installations, one antenna will serve more than one receiver. Where this type of installation is used, a simple cross-check of receivers will be sufficient to localize the trouble.

8-3. There will be installations where the simple system is a part of a large system. Where this is true, there will be a variety of checks that can be made to determine if the antenna, cable, or reciver is at fault. Again look at figure 2 and you will see that in the large installation the simple system is connected to the overall system; thus, an overall check is possible with monitors or built-in test equipment to localize trouble areas.

8-4. **Complex System.** The term "complex system" is used to have a point of reference. The complex system can be represented by figure 2 or it could have fewer units as well as more units to make up the overall system. Logical reasoning tells us that there is little interaction between units of the simple system to complicate any system analysis. In the complex system this is not the case, as a trouble in one area can affect the entire system.

8-5. Assume that only a portion of the system is in operation—the tape machine, the distribution amplifier, and monitors. In this instance if a video image is not obtained on a monitor, the trouble could be in the cables, switcher, distribution amplifiers, or tape machine. An open cable between the switcher and the monitor would cause a loss of image; however, this trouble could be checked by using a known good monitor. Also a faulty distribution amplifier could cause the same symptom, but substitution would aid in localizing the faulty unit. If the tape machine were faulty, then when video on a monitor was lost, all monitors would have the same indications. A check with the tape machine video monitor and the tape machine waveform monitor will quickly indicate that the tape machine is the trouble source.

8-6. The distribution amplifier unit can be affected by a monitor in such a manner to cause it to blow a fuse and thus affect the rest of the system. This would be the same as discussed in the previous section on transmission distribution amplifiers. The distribution amplifier power supply unit failure would have the same effect, in that it would affect more than one distribution amplifier. This would also affect all monitors attached to the distribution amplifier units the same as would be revealed by a cross-check of monitors.

8-7. The complex system will enable a more comprehensive study of system troubles. When troubleshooting a system, always remember to use all available symptoms, learn to read the symptoms, and analyze them to determine the unit which is faulty. Never fail to compare system symptoms as this will lead to a rapid repair and thus keep a system on the air. If a signal does not reach its destination, regardless of the cause, then efficiency is lost. Therefore all parts of the system are important, as you will see from the planning involved in system installation, as covered in the next chapter.

MODIFICATIONS

Chapter 4 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

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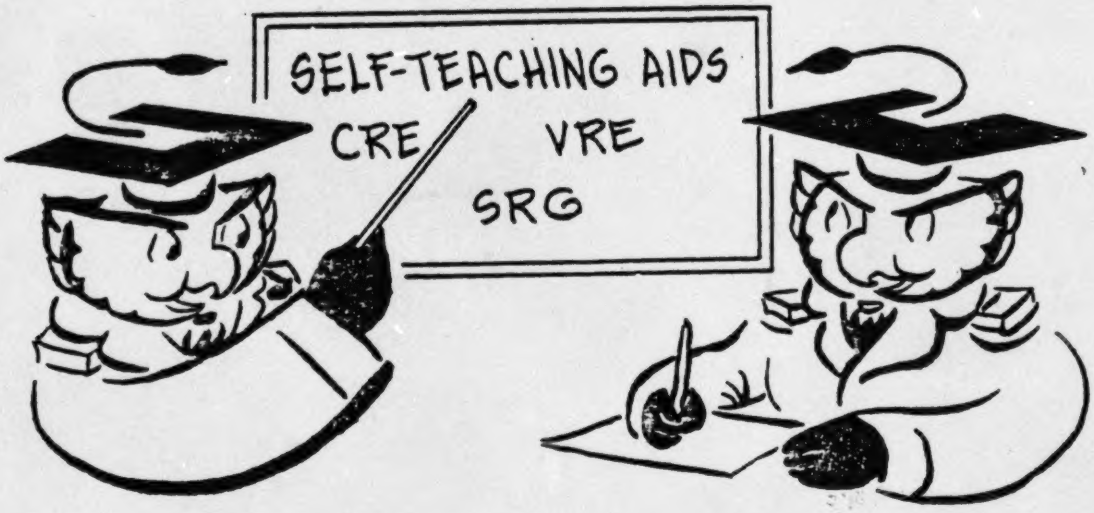
WORKBOOK

TELEVISION EQUIPMENT REPAIRMAN/TECHNICIAN



This workbook places the materials you need *where* you need them while you are studying. In it, you will find the Study Reference Guide, the Chapter Review Exercises and their answers, and the Volume Review Exercise. You can easily compare textual references with chapter exercise items without flipping pages back and forth in your text. You will not misplace any one of these essential study materials. You will have a single reference pamphlet in the proper sequence for learning.

These devices in your workbook are autoinstructional aids. They take the place of the teacher who would be directing your progress if you were in a classroom. The workbook puts these self-teachers into one booklet. If you will follow the study plan given in "Your Key to Career Development," which is in your course packet, you will be leading yourself by easily learned steps to mastery of your text.

If you have any questions which you cannot answer by referring to "Your Key to Career Development" or your course material, use ECI Form 17, "Student Request for Assistance," identify yourself and your inquiry fully and send it to ECI.

Keep the rest of this workbook in your files. Do not return any other part of it to ECI.

EXTENSION COURSE INSTITUTE
Air University

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ECI Form No. 17

STUDY REFERENCE GUIDE

1. *Use this Guide as a Study Aid.* It emphasizes all important study areas of this volume.

2. *Use the Guide as you complete the Volume Review Exercise and for Review after Feedback on the Results.* After each item number on your VRE is a three digit number in parenthesis. That number corresponds to the Guide Number in this Study Reference Guide which shows you where the answer to that VRE item can be found in the text. When answering the items in your VRE, refer to the areas in the text indicated by these Guide Numbers. The VRE results will be sent to you on a postcard which will list the *actual VRE items you missed.* Go to your VRE booklet and locate the Guide Number for each item missed. List these Guide Numbers. Then go back to your textbook and carefully review the areas covered by these Guide Numbers. Review the entire VRE again before you take the closed-book Course Examination.

3. *Use the Guide for Follow-up after you complete the Course Examination.* The CE results will be sent to you on a postcard, which will indicate "Satisfactory" or "Unsatisfactory" completion. The card will list *Guide Numbers* relating to the questions missed. Locate these numbers in the Guide and draw a line under the Guide Number, topic, and reference. Review these areas to insure your mastery of the course.

Guide Number	*Guide Numbers 300 through 315*
300	Operational Responsibilities; Systems, pages 1-2
301	Inspection: Daily; Weekly; Monthly, pages 2-4
302	Inspection: Two Months (60 Days); Three Months (90 Days); Semiannual; Annual; Inspection Teams; Evaluation of Inspection Reports, pages 4-6
303	System Quality Checks, pages 6-7
304	Troubleshooting and Repair; Television Test Equipment, Types, Use, and Malfunctions: Television Test Equipment; Color Television Testing, pages 8-10
305	Television Test Equipment, Types, Use, and Malfunctions: Test Equipment Malfunctions and Detection; Alternate Quality Testing Methods; Transistor Checks, pages 10-13
306	Troubleshooting and Maintenance Procedures, pages 13-14
307	Systematic Repair, pages 14-17
308	Diagnosing System Troubles; Transmission System Troubles: Power Supply; Sync Generator; Camera; Switcher, pages 18-20
309	Transmission System Troubles: Distribution Amplifiers; Monitor; Exciter; Transmitting Antenna, pages 20-22
310	Receiving System Troubles, pages 22-24
311	Installation and Modification; C-E Programming: C-E Requirements; Planning; Planning Qualitative and Quantitative C-E Requirements; Programming; Programming Qualitative and Quantitative C-E Requirements, pages 25-28
312	C-E Programming; Programming Television Requirements; C-E Program Management; Implementation; Implementing Qualitative and Quantative C-E Requirements; C-E Schemes; C-E Implementation Schedule; Implementing Television Requirements, pages 28-30
313	Installation Phase, pages 30-32
314	Installation Testing, Inspection and Acceptance, pages 32-35
315	Modifications, pages 35-38

*NOTE: Pages 494 and 495 are missing due to deleted material. No pertinent information was omitted.

2. Match the following items of test equipment with the appropriate statement. (4-3-12, 36)

_____ *a.* Tube checker.
_____ *b.* Wattmeter.
_____ *c.* Voltmeters and milliammeters.
_____ *d.* Ohmmeter.
_____ e. Grating generator.
_____ *f.* Dummy load.
_____ *g.* Multiburst generator.
_____ *h.* Video sweep generator.
_____ *i.* Oscilloscope.
_____ *j.* Monoscope amplifier.
_____ *k.* Waveform monitor.

1. Used for regulated power supply tests.
2. Checks deflection linearity.
3. Prevents r-f interference during transmitter testing.
4. Provides modulating signal for transmitter testing.
5. Provides accurate voltage measurements.
6. Checks transmitter output power.
7. Checks video circuit bandwidth.
8. Checks system pulse widths.
9. Produces video and other timed pulses.
10. Check for matched tubes.
11. Alternate transistor test.

3. Identify the test equipment specially designed for color testing. (4-13)

4. What is the best method of troubleshooting a color bar generator? (4-26)

5. Give the best alternate method of testing the frequency response of a television system if the multiburst generator should fail and describe how irregularities are identified. (4-33, 34)

6. Name the video quality tests that can be made using the EIA resolution test pattern. (4-36)

7. How do you check a p-n-p transistor with an ohmmeter? (4-46)

8. Name the steps associated with troubleshooting and repairing television equipment. (5-2)

9. Describe the similarities of symptom analysis and trouble analysis. (5-4, 6)

10. What conditions may result in recurring circuit malfunctions? (5-8)

11. Why are intricate maintenance procedures written? Give three examples of these procedures. (5-9)

12. How are alignment and calibration procedures written? (5-13)

13. What precautions should be taken during disassembly of television equipment? (6-3)

14. What are the advantages of using bench mockups for equipment checkout? (6-8)

15 What are the disadvantages of not using bench mockups for equipment checkout? (6-9)

16. Why are quality checks desirable? (6-10)

17. Who is responsible for the calibration of precision measuring equipment? (6-27)

18. Who is responsible for processing new items of precision measuring equipment through the PMEL? (6-35)

CHAPTER 3

Objectives: To describe the procedures used in analyzing system symptoms to determine the malfunctioning units in the system.

1. Number the following events in their proper sequence as they relate to systems maintenance. (7-1, 2)

______*a.* Isolate trouble.
______*b.* Recognize symptoms.
______c. Cross-check symptoms.
______*d.* Verify symptoms by substitution.
______e. Localize symptom to unit of system.
______*f.* Analyze symptoms.
______*g.* Verify unit at fault by substitution.
______*h.* Repair or replace unit at fault.

2. Which of the following items can be matched to the associated statement(s)? (7-4-7)

________a. A fuse.
________b. A time-delay device.
________c. A control relay.

1. Can be bad and there will not be any power to the pilot light.
2. Malfunctioning will cause a loss of current and voltage output.
3. Working improperly; could cause voltages to be applied too quickly.
4. Could possibly be a cause of the pilot light not working.

3. In a closed circuit cable system, a monitor indicates erratic horizontal tearing of the image. List the system units which could cause this. (7-8-10)

4. If you have high-frequency loss in a camera preamplifier, what would be the symptoms and what would be adjusted to compensate for the loss? (7-12)

5. What unit of the system would cause an instantaneous video presentation, but would also cause the presentation to drop out just as quickly? (7-15)

6. Three monitors have lost their signal but the other monitors all have good signals. What is the most likely cause of the trouble? (7-16-22)

7. What would be the symptoms if a monitor input becomes shorted? (7-24)

8. List the various methods of using an exciter unit as related to the various types of TV r-f transmissions. (7-25-30)

9. If you were told that a slight misalignment of antennas had caused a complete loss of signal. what basic category of antennas would this probably be? (7-31-33)

10. Which signals would be affected on a TV receiver if the antenna cable is broken? (8-2)

11. How would a simple system, installed as part of a complex system, be an aid to trouble analysis? (8-3, 4)

MODIFICATIONS

Pages 9 - 13 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

ANSWERS FOR CHAPTER REVIEW EXERCISES

CHAPTER 2

1. Multiburst generator; grating generator; monoscope amplifier; and waveform monitor. (4-2)
2. 1, *c*; 2, *e*; 3, *f*; 4, *j*; 5, *i*; 6, *b*; 7, *h*; 8, *k*; 9, *g*; 10, *a*; and 11, *d*. (4-3-12, 46)
3. Color bar generator, dot generator, vectorscope, color signal analyzer, and linearity checker. (4-13)
4. Signal tracing. (4-26)
5. The EIA resolution test pattern. Characteristic response frequency irregularities appear in the output presentation as closely spaced, horizontally displaced, positive or negative, delayed or advanced repetitions of the original signal. These discrepancies are called ringing. (4-33, 34)
6. Gray-scale rendition, shading, uniformity, streaking, interlace, aspect ratio, geometric distortion, horizontal and vertical resolution, and characteristic response frequency. (4-36)
7. Base to emitter and base to collector front to back ratio. (4-46)
8. Symptom recognition, symptom analysis, trouble localization, trouble analysis, and trouble correction. (5-2)
9. Both are evaluations of known factors. (5-4, 6)
10. Faulty circuit design and unrepaired component or circuit defects. (5-8)
11. To remember all necessary steps. Alignment, calibration, and PMI's. (5-9)
12. In simple, logical, straightforward steps. (5-13)
13. Do not perform more disassembly than necessary, follow TO's and manufacturer's handbooks, do not lose components and other parts, and label wiring as it is disconnected. (6-3)

14. They are permanently set up, they are available at all times, they permit easy alignment, calibration, and final checkout of equipment. (6-8)

15. Possible checkout delays and test equipment must be set up each time it is used. (6-9)

16. To insure that repair is properly completed to locate need for additional training, and to prevent equipment and system damage. (6-10)

17. All personnel engaged in organizational, field, and depot level maintenance of precision measuring equipment. (6-27)

18. The using organization. (6-35)

CHAPTER 3

1. *a.* 7.
   b. 1.
   c. 2.
   d. 3.
   e. 5.
   f. 4.
   g. 6.
   h. 8.
   (7-1, 2)

2. *a.* 1.
   b. 3 and 4.
   c. 2.
   (7-4-7)

3. Monitor (horizontal oscillator), distribution amplifier, and sync generator. (7-8-10)

4. The symptom would be white streaks in the video presentation, and the adjustment of the high-peaker should correct the problem. (7-12)

5. The switcher would cause this symptom if its switch contacts are bad. There would be a momentary video presentation due to the pressure of the operator pushing the button. (7-15)

6. A video distribution amplifier used as a line amplifier for the three monitors. It could be a line going to the distribution amplifier, but this is a less likely problem. (7-16-22)

7. There would not be a video presentation on that particular monitor or other monitors connected to the same distribution amplifier. A short on a monitor input will cause a distribution amplifier fuse to blow due to the excessive current at the distribution amplifier output. (7-24)

8. Cable video only, r-f carrier; cable video and audio, r-f carrier; relay radiated video and audio, r-f carrier; broadcast radiated video, AM carrier; broadcast radiated audio, FM carrier. (7-25-30)

9. Microwave relay antennas, because they are a highly directional low-power antenna; thus a slight misalignment can cause complete loss of power. (7-31-33)

10. Both the video and audio signals as they are separated internally; thus a broken cable will cause a loss of all signals. (8-2)

11. The simple system could be used to insert a test signal, and it can be used to receive and thus compare signals. This enables the checking of inputs to the complex system. (8-3, 4)

*NOTE: Pages 504 and 505 are missing due to deleted material. No pertinent material was omitted.

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STOP– 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER. 2. USE NUMBER 1 PENCIL.

30455 03 21

VOLUME REVIEW EXERCISE

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use only medium sharp #1 black lead pencil for marking answer sheet.
4. Use a clean eraser for any answer sheet changes, keeping erasures to a minimum.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than with a #1 black lead pencil.

Note: The 3-digit number in parenthesis immediately following each item number in this Volume Review Exercise represents a Guide Number in the Study Reference Guide which in turn indicates the area of the text where the answer to that item can be found. For proper use of these Guide Numbers in assisting you with your Volume Review Exercise, read carefully the instructions in the heading of the Study Reference Guide.

Multiple Choice

Note: The first three items in this exercise are based on instructions that were included with your course materials. The correctness or incorrectness of your answers to these items will be reflected in your total score. There are no Study Reference Guide subject-area numbers for these first three items.

1. The form number of this VRE (or CE) must match

   a. my course number.
   b. the number of the Shipping List.
   c. the form number on the answer sheet.
   d. my course volume number.

2. So that the electronic scanner can properly score my answer sheet, I must mark my answers with a

   a. pen with blue ink.
   b. ball point or liquid-lead pen.
   c. number 1 black lead pencil.
   d. pen with black ink.

3. If I tape, staple or mutilate my answer sheet; or if I do not cleanly erase when I make changes on the sheet; or if I write over the numbers and symbols along the top margin of the sheet,

   a. I will receive a new answer sheet.
   b. my answer sheet will be unscored or scored incorrectly.
   c. I will be required to retake the VRE (or CE).
   d. my answer sheet will be hand-graded.

Chapter 2

10. (306) What functions are involved during the trouble correction phase of troubleshooting and repair of TV equipment?

    a. Disassembly, replacement, repair, and reassembly.
    b. Disassembly, replacement, repair, evaluation, and reassembly.
    c. Disassembly, repair, reassembly, and inspection.
    d. Disassembly, replacement, reassembly, and inspection.

11. (304) What unit of TV test equipment is used for contrast, deflection linearity, low-frequency phase shift, and resolution tests?

    a. The waveform monitor.
    b. The monoscope amplifier (camera).
    c. The grating generator.
    d. The multiburst generator.

12. (306) What steps (not necessarily in logical order) are involved in the systematic process of troubleshooting and repair of TV equipment?

    a. Trouble localization, trouble analysis, disassembly, correction, and reassembly.
    b. Disassembly, replacement, repair, and reassembly.
    c. Symptom recognition, correction, trouble localization, symptom analysis, and trouble analysis.
    d. Symptom recognition, trouble analysis, disassembly, repair, and reassembly.

13. (304) Which of the following units of test equipment are used for color testing?

    a. The vectorscope, color signal analyzer, and linearity checker.
    b. The vectorscope, color signal analyzer, and multiburst generator.
    c. The vectorscope, monoscope amplifier, and color-bar generator.
    d. The vectorscope, video sweep generator, and linearity checker.

14. (305) What video quality tests can be made using the EIA resolution test pattern?

    a. Streaking, interlace, aspect ratio, and color fidelity.
    b. Gray-scale rendition, aspect ratio, streaking, and geometric distortion.
    c. Interlace, aspect ratio, frequency response, and color fidelity.
    d. Aspect ratio, shading, vertical resolution, and horizontal amplitude.

15. (307) Who is responsible for processing new items of precision-measuring equipment through the PMEL?

    a. The PMEL.
    b. Base supply.
    c. The using organization.
    d. The Calibration and Meteorology Division.

16. (307) Why are quality checks necessary?

    a. To prevent equipment damage.
    b. To complete repairs.
    c. To discover poor workmanship.
    d. To increase training needs.

17. (305) What is the best method of troubleshooting a color-bar generator?

    a. Voltage checks.
    b. Signal tracing with an oscilloscope.
    c. Resistance checks.
    d. Pulse amplitude checks with an oscilloscope.

18. (307) Why are alternate checkout methods less desirable than bench mockups?

    a. Increased time outage of the operational equipment.
    b. Increased repair time.
    c. Scheduled programming is interrupted.
    d. Test equipment must be set up when it is used.

19. (306) Why are detailed maintenance procedures written?

    a. To complete proper alignment and calibration of the equipment.
    b. To complete the proper PMI's.
    c. To insure completion of all necessary maintenance tasks.
    d. To complete all necessary alignment procedures.

20. (306) What conditions do recurring malfunctions usually indicate?

    a. Faulty circuit design and modification.
    b. Unrepaired circuit components and excessive equipment failures.
    c. Unrepaired circuit components and modifications.
    d. Faulty circuit design and unrepaired circuit components.

Chapter 3

21. (308) A monitor has erratic tearing of the horizontal image. Which of the following groups is most likely the cause?

    a. Monitor (horizontal oscillator), transmitter, and sync generator.
    b. Distribution amplifier, camera, and sync generator.
    c. Monitor (horizontal oscillator), distribution amplifier, and sync generator.
    d. Monitor (horizontal oscillator), power supply, and sync generator.

22. (309) What would be the most correct symptoms if a monitor input were to become shorted?

    a. No video presentation and a blown fuse in the distribution amplifier.
    b. No video presentation on one monitor, but all others would be normal.
    c. There would probably be a weak video signal present on the monitor.
    d. The video signal would have a vertical roll due to change of impedance.

23. (310) How would the incoming signal to a color TV receiver be affected if the antenna cable conductor is broken?

    a. The video will become weak.
    b. All incoming signals will be lost.
    c. Only the color burst signal will be lost.
    d. The audio will become weak.

24. (309) Which of the following systems would normally use an r-f exciter unit to generate a carrier signal to be modulated by video?

    a. Single camera and monitor, used for doorway surveillance.
    b. Studio camera to tape machine for making tapes.
    c. Studio-to-transmitter relay.
    d. Switcher to tape machine for making tapes.

MODIFICATIONS

Pages 22-26 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

LIST OF CHANGES

COURSE NO. 30455	CAREER FIELDS, POLICIES, PROCEDURES AND EQUIPMENT CHANGE. ALSO ERRORS OCCASIONALLY GET INTO PRINT. THE FOLLOWING ITEMS UPDATE AND CORRECT YOUR COURSE MATERIALS. PLEASE MAKE THE INDICATED CHANGES.
EFFECTIVE DATE OF SHIPPING LIST 7 Apr 76	

7. CHANGES FOR THE VOLUME WORKBOOK: VOLUME 1A

e. Page 35, Special Situation instructions preceding question 64, line 1: Change "test" to "text." Line 2: Change "as follows" to "initially for each question."

f. Page 36, Special Situation instructions, question 68: Change "up as follows" to "initially for each question."

g. The following questions are no longer scored and need not be answered: 32 and 36.

8. CHANGES FOR THE VOLUME WORKBOOK: VOLUME 2

a. Page 30, Chapter Review Exercise, answer 11: Change "radiated" to "received."

b. The following questions are no longer scored and need not be answered: 24, 27 and 67.

9. CHANGE FOR THE VOLUME WORKBOOK: VOLUME 3

The following questions are no longer scored and need not be answered: 22, 40 and 45.

NOTE: Change the currency date on all volumes to "15 December 1974."

LIST OF CHANGES

COURSE NO. 30455	CAREER FIELDS, POLICIES, PROCEDURES AND EQUIPMENT CHANGE. ALSO ERRORS OCCASIONALLY GET INTO PRINT. THE FOLLOWING ITEMS UPDATE AND CORRECT YOUR COURSE MATERIALS. PLEASE MAKE THE INDICATED CHANGES.
EFFECTIVE DATE OF SHIPPING LIST 7 Apr 76	

1. CHANGES FOR THE TEXT: VOLUME 1

a. Preface, page iii, line 2: Change sentence to read ". . . achievement of 5-level proficiency." Lines 4 and 5: Delete sentence which reads "If you are training to . . . in addition to this course." Lines 7 and 8: Change sentence to read "Such items are contained in CDC 30000 for 5-skill level training."

b. Page 6, Fig 1: At the 5 skill level, change "1098" to "2095." At the 7 skill level, change "1098" to "2096."

c. Page 51, col 1, line 3: Change "you will" to "possibly."

d. Page 90, Fig 83: Change secondary of input transformer to center tapped. Label upper transistor Q1 and lower transistor Q2. Add tie point at the junction of the emitters of both transistors and ground.

2. CHANGES FOR THE CHANGE SUPPLEMENT: VOLUME 1 (30455 01 S01 0569)

a. Page 1, col 1, lines 8 and 9: Change "Tech Tng Ctr (TSOC), Keesler AFB, MS 39534" to "USAF School of Applied Aerospace Sciences (TTOX), Lowry AFB, CO 80230."

b. Page 1, under "Workbook" changes: Beginning with page 18, changes should be reflected under Changes for the Text.

c. Page 1, Changes for the Workbook, line 5: Delete "Change CDA to DCA."

3. CHANGE FOR THE TEXT: VOLUME 1A

Page iii, lines 24 and 25: Change "Tech Tng Ctr (TSOC), Keesler AFB, MS 39534" to "USAF School of Applied Aerospace Sciences (TTOX), Lowry AFB, CO 80230."

4. CHANGE FOR THE TEXT: VOLUME 2

Page iii, lines 20 and 21: Change "Tech Tng Ctr (TSOC), Keesler AFB, MS 39534" to "USAF School of Applied Aerospace Sciences (TTOX), Lowry AFB, CO 80230."

5. CHANGE FOR THE TEXT: VOLUME 3

Page iii, lines 15 and 16: Change "Tech Tng Ctr (TSOC), Keesler AFB, MS 39534" to "USAF School of Applied Aerospace Sciences (TTOX), Lowry AFB, CO 80230."

6. CHANGES FOR THE VOLUME WORKBOOK: VOLUME 1

a. Page 7, Chapter Review Exercise, question 10, line 3: Change "(7; Fig. 31)"

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LIST OF CHANGES

COURSE NO.
30455

EFFECTIVE DATE OF SHIPPING LIST
7 Apr 76

CAREER FIELDS, POLICIES, PROCEDURES AND EQUIPMENT CHANGE. ALSO ERRORS OCCASIONALLY GET INTO PRINT. THE FOLLOWING ITEMS UPDATE AND CORRECT YOUR COURSE MATERIALS. PLEASE MAKE THE INDICATED CHANGES.

6. CHANGES FOR THE VOLUME WORKBOOK: VOLUME 1 (Continued)

to "(7-9; Fig. 31)." Question 11, lines 2 and 3: Change "16-17-Kc" to "16.7Kc."

b. Page 8, Chapter Review Exercise, question 13, line 1: Change "31" to "30."

c. Page 11, Chapter Review Exercise, question 21, lines 3 and 4: After "no" add "horizontal."

d. Page 14, Chapter Review Exercise, question 22, col B: Change "grid" to "heater" in choice b.

e. Page 18, Chapter Review Exercise, question 16: Change "How can the color camera IO be adjusted?" to read "What provision is made to equalize the gain of the IO tubes in a color camera?"

f. Page 22, Chapter Review Exercise, col 2, answer 10: Change "(7; Fig 31.)" to "(7-9; Fig 31.)"

g. Page 24, Chapter Review Exercise, answer 12, line 3: Change "(at TP3)" to "(at TP6)." Answer 17, line 2: Change "oscillator" to "monitor."

h. Page 34, question 69: Change "(121)" to read "(122)."

i. The following questions are no longer scored and need not be answered: 9, 41 and 63.

7. CHANGES FOR THE VOLUME WORKBOOK: VOLUME 1A

a. Page 7, Chapter Review Exercise, question 25: Change "(10-10)" to "(10-15)." Question 26: Change "(10-15)" to "(10-13)."

b. Page 20, Chapter Review Exercise, answer 26: Change "control" to "management." Answer 29: Change "310E" to "210E."

c. Page 21, Chapter Review Exercise, answer 40: Change "213" to "187." Answer 43: Change "extra copy" to "a shop."

d. Page 24, Chapter Review Exercise, answer 23: Change "$\frac{10}{4.73 \text{ X } 105}$" to "$\frac{10}{4.73 \text{ X } 10^5}$" Answer 29: Change "TO 33K-1-01, Calibration Procedures and Responsibilities" to "TO 33K-1-100, Responsibilities and Calibration Measurement Areas."